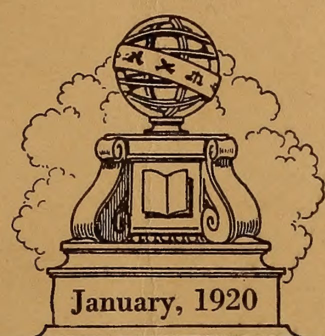
SCIENTIFIC AMERICAN MONTHLY

FORMERLY SCIENTIFIC AMERICAN SUPPLEMENT



How Men Walk With Artificial Legs

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Aerial "Diving Suits" and "Submarines"

Effect of Light on Plants

The Death of a Big Gun

Wireless Storm Detector for the Central Station

Automatic Regulation of Humidity in Factories

General Applications of Selenium

Logging With Belt-Tread Tractors

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To further the extension of scientific research in American industries.

To publish the more important announcements of distinguished technologists, appearing in foreign as well as domestic publications.

To furnish translations of the complete text of significant articles in European periodicals.

To keep the busy man posted on the progress of technology in all fields by publishing abstracts of current literature.

To reflect the most advanced thought in science and technology throughout the world.

SCIENTIFIC AMERICAN MONTHLY

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SCIENTIFIC AMERICAN MONTHLY
(Successor to Scientific American Supplement)

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USING A RUBBER BOTTLE TO FORCE WATER AND ACID INTO A CARAFE SO AS TO CLEAN OUT ANY SEDIMENT IT MIGHT CONTAIN. (SEE PAGE 30.)

SCIENTIFIC AMERICAN MONTHLY

VOLUME I
NUMBER 1

NEW YORK, JANUARY, 1920

40 CENTS A COPY
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SUCCESSOR TO THE SCIENTIFIC AMERICAN SUPPLEMENT.

IN the SCIENTIFIC AMERICAN of December 4, 1875, a new journal was announced to be known as the SCIENTIFIC AMERICAN SUPPLEMENT. It was a momentous period in our national history. Our industries had fully recovered from the ravages of the Civil War, and at this the one hundredth anniversary of the founding of our Republic, we were going to demonstrate to the world by a great International Exposition the progress we had made in the arts and sciences. There was a wide-spread interest in technology and it was felt by the publishers of the SCIENTIFIC AMERICAN that there was a need for a journal which would meet the desire for information of a more technical character than could properly be published in the SCIENTIFIC AMERICAN. The wisdom of publishing the SUPPLEMENT was demonstrated when the first issue bearing date of January 1, 1876, was placed on sale a week in advance of that date and all copies were exhausted before the first of the year, making it necessary to publish a second edition.

We have come to another such momentous period in our history. Again we feel that a special journal is demanded to meet the requirements of the time. The great war has awakened in the American public, as in the world at large, a wide-spread interest in science, both pure and applied. During the war we had to turn to science for help. There was scarcely any branch of science from astronomy to geology, from meteorology to psychology that was not called upon to solve the problems that arose. Our university professors were enlisted in the cause, and they rendered invaluable service. Never before has science had such an opportunity to demonstrate its worth, and the demonstration it gave has converted the general public from an attitude of mild contempt to one of deepest respect.

Even before we were directly involved in the war, the sudden cutting off of supplies from Germany made us realize that our only road to real independence lay in enlisting the help of science to show us how to make with our own hands the products which we had previously bought from foreign countries. As a consequence, there is a wide and growing demand for research in all fields of technology. Furthermore, the public has been educated to the necessity of keeping posted on the progress of science. Engineers, manufacturers, business men, all realize more fully than ever before the interrelation between various branches of technology. No longer may a man confine his reading to his own class or technical journals. He must keep track of the march of science in contiguous and apparently remote fields.

To meet this need, we have determined to supplant the SCIENTIFIC AMERICAN SUPPLEMENT with a new journal much broadened in scope. The news that is of immediate importance which often receives erroneous or superficial treatment in the daily press is amply supplied in the weekly SCIENTIFIC AMERICAN and so it seems eminently fitting that the more serious or larger articles which are worthy of publication should be treated of in a *monthly* journal. Hence we are publishing the new journal as a monthly magazine of ninety-six text pages which will give us ample room for all the new features we wish to include. The SCIENTIFIC AMERICAN MONTHLY is naturally a distinct publication from the weekly SCIENTIFIC AMERICAN, but at the same time it will be closely allied with that journal. Many important topics which, owing to the limitations of space can be referred to only briefly in the latter, will be published in full in the monthly journal, thus making the new journal a most important if not an absolutely indispensable adjunct to the SCIENTIFIC AMERICAN.

We shall continue our policy of publishing the more important announcements of distinguished scientists appearing in foreign as well as domestic publications, thereby reflecting the most advanced thought in science and technology throughout the world. In these columns will be found the complete text of significant European articles, furnishing, often, the only translation of these papers obtainable.

In order to keep our readers abreast of the times, we have arranged with the American Society of Mechanical Engineers and also with the American Institute of Mining and Metallurgical Engineers to supply us each month with summaries of the more important articles and papers dealing with their respective fields of technology. In each case the source of the article will be given so that the reader may study the complete original text if he so desires. In a similar manner the fields of applied chemistry and electricity are covered by digests of the more important articles appearing in the chemical and electrical journals. This feature of the SCIENTIFIC AMERICAN MONTHLY will be invaluable to a wide circle of readers and especially to progressive manufacturers.

We wish to call particular attention to the department devoted to the work of the National Research Council. This department will be used as an *official organ* of the National Research Council to keep the public informed of the work that the Council is doing in organizing scientific research and introducing it into our industries. It is one of the aims of the Council to make science as important an adjunct of manufacture in this country as it is in Germany.

We are endeavoring in every way to make the SCIENTIFIC AMERICAN MONTHLY a most useful journal for the manufacturer and an interesting one for the general reader as well. For this reason, we are including in our columns the recent advances in pure as well as applied science. We shall welcome constructive criticism from any of our readers.—EDITOR.

Improvised Orthopedic Exercising Apparatus*

Specialized Corrective Gymnastic Exercises for Soldiers and Recruits

Rudolph S. Reich, M.D., Captain, M. C., U. S. Army, Fort Sheridan, Ill.

During June, 1918, at Camp Cody, New Mexico, the camp orthopedic staff was confronted with the necessity of carrying out on a large scale, many specialized corrective gymnastic exercises for soldiers and recruits among whom were found all of the whole gamut of orthopedic defects: weak feet; contractures of the finger, wrist and larger joints; limitation of motion of various joints incident to recent fractures, etc. For this work, the medical department provided the orthopedic staff absolutely nothing in the way of ready-made orthopedic apparatus, such as Zander machines, and at that time the principles of vocational reconstruction had not made such appliances available. The schedule of gymnastics included specialized calisthenic exercise without apparatus, supplemented by a general daily routine suited to the individual needs of the men. Although excellent results were secured, it seemed to me that the end results might be augmented by the employment of apparatus designed to assist in corrective and developmental work.

APPARATUS FOR THE LOWER EXTREMITY

Realizing the need of apparatus to facilitate flexion and extension of the foot and knee, we devised wooden steps, having a rise of 6 inches and a tread of the same dimension, arranged in such a way that the patient walked up four and down the same number. Wooden hurdles, 8 inches high, were made (Fig. 1). These were placed at variable distances, and each man stepped over them in such a way that his foot passed directly over the hurdle, necessitating flexion and extension at the knee, and extension of the foot.

The success of this simple device, which was no doubt partly due to its novelty, encouraged us in attempting other appliances. We tried to procure an old sewing machine to stimulate dorsal and plantar flexion by pedaling, but were unable to do so, and decided to build its equivalent. Through the courtesy of the reclamation and conservation officer, we obtained a fly-wheel of a washing machine. Short pieces of various sizes of lumber were obtained through the courtesy of the construction quartermaster. A frame, 36 inches high and 24 inches square (Fig. 2), was constructed out of two-by-fours. An offset was attached to the right side, and in the inside of the frame, to which was attached the fly-wheel, 24 inches in diameter. The foot-pedal, which was the chief mechanical feature, made of 2 by 10 lumber, rested on an elevation from the base, which was similar to that of a sewing machine, and it was joined to the fly-wheel by means of a wooden connection rod. The patient's seat was built to the frame, and his feet were strapped to the pedal. The efforts to forcc the fly-wheel gave the desired dorsal and plantar flexion with resistance, which was graduated by an adjustable brake.

Another machine, similar to the one described, was constructed, in which the pedal was hinged to the frame in such a way as to bring the fulcrum at the far end of the pedal, and in this way a wider range of dorsal and plantar flexion was obtained.

The Red Cross obtained for us an old bicycle, which included the frame, saddle, sprocket, chain, and rear axle and gear only. This was fixed upright on the floor by means of a wooden frame. (Fig. 3), and a rear wheel was constructed entirely of wood. Pedals, which were 10 inches long, also had to be improvised of wood. The feet were strapped to them, and, by putting the pedals into motion, flexion and extension of the hips and knees, as well as dorsal and plantar flexion, were obtained. Resistance was graduated as in the other apparatus, by means of a brake.

For patients afflicted with weak feet, with abduction and pronation, we used boards (Fig. 4) on which men received systematic exercises in their bare feet. Short strips of 2 by 10 lumber, 12 inches long, were cut down into double inclined planes of 120 degrees, with the apexes upward. The distal end of the board was cut to a point forming an angle of 120 degrees, and this point was notched out into a semicircle. In this way, dorsal and plantar flexion were easily obtained from the metatarsophalangeal joint, when the man sood on the board with his feet parallel and 3 inches apart, and his toes over the distal end of the board, while the incline placed the feet in adduction and supination.

For the same purpose, a long runway was constructed in the shape of a double inclined plane, with the apex pointing upward at an angle of 120 degrees, and the men were instructed to walk along this incline with feet parallel, or toeing slightly inward.

*Read before the Section on Orthopedic Surgery at the Seventieth Annual Session of the American Medical Association.

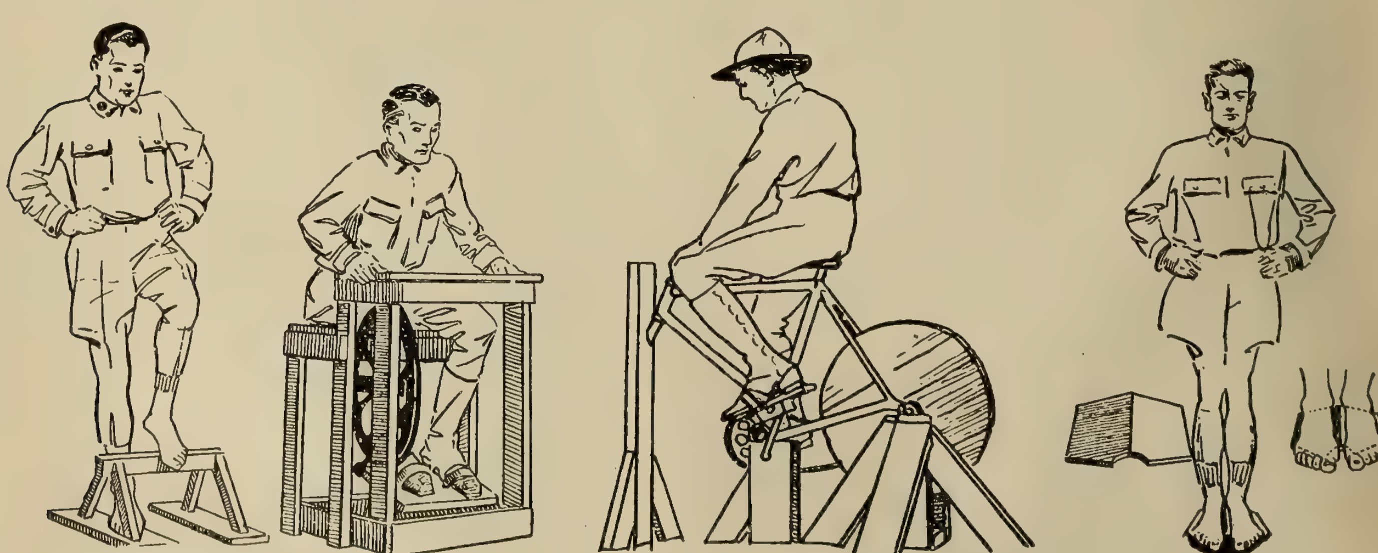


FIG. 1. THE HURDLE FIG. 2. PEDALING MACHINE FIG. 3. THE DUMMY BICYCLE FIG. 4. FOOT-EXERCISING BOARD

SOME IMPROVISED APPARATUS FOR EXERCISING THE ANKLE AND KNEE

FIG. 5. A WASHING MACHINE FLY-WHEEL AS A SHOULDER CIRCUMDUCTION MACHINE

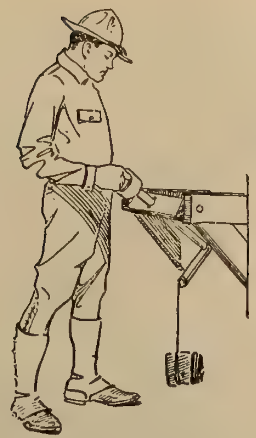


FIG. 6. PRONATION AND SUPENATION APPARATUS

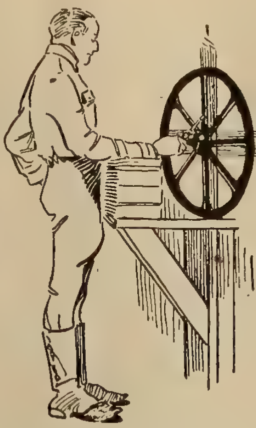


FIG. 7. WRIST CIRCUMDUCTION APPARATUS

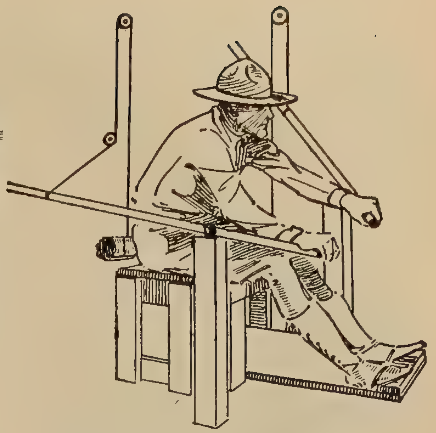


FIG. 8. AN IMPROVISED ROWING MACHINE USED FOR GENERAL EXERCISE

APPARATUS FOR THE UPPER EXTREMITY

In considering apparatus for the upper extremity, we first attempted to construct exercisers. The available materials consisted of discarded pulleys, rope and old shell casings filled with sand for weights. Handles were made from broom sticks and No. 6 galvanized iron wire. Three types were constructed: The first in which the pull was from above downward and required only two pulleys, firmly attached to the ceiling, over which the rope was suspended with the weights and handles on either side. The second, in which the pull was on a horizontal plane and required four pulleys. The first two were attached to the wall, 4 feet from the floor, and 2 feet apart. The second two were suspended from the wall 3 feet above and 6 inches to the outside of the vertical plane of the lower pair. The rope extended from the handles through the lower set of pulleys, then through the upper set, and to the shell casings. In the third type, the pull was from below upward, and also required four pulleys. The first two pulleys were attached to the floor at the junction of the wall and 3 feet apart, and the second two were attached to the wall 6 feet above and 6 inches to the outside of the vertical plane of the lower ones. From the handles, the rope extended first through the lower set of pulleys, then through the upper set, and finally to the weights.

For exercising the deltoid muscle and for producing circumduction of the shoulder joint, we employed a large fly-wheel, 30 inches in diameter, salvaged from a washing machine (Fig. 5). This wheel revolved on an axle which was fixed at one end to a metal bracket, a part of the original washing machine. It was mounted on a wooden offset 5 feet from the floor, and in such a way that the axle projected horizontally at right angles to the wall. A wooden handle was inserted into the rim, and a wooden brake was applied against the rim, the pressure being regulated to suit the needs of the patients.

An apparatus for pronation and supination exercise of the forearm was thus constructed: A piece of two-by-four about 20 inches long was trimmed down at each end to leave two cylindric projections like the handles of a rolling-pin (Fig. 6). It was mounted on a pair of wooden brackets fastened to the wall, 30 inches from the floor, in a position similar to that for a roller towel rack, and was then perforated in the center at right angles to its long axis, a hole being made of the right size to receive snugly the shaft of a sawed-off shovel handle, which was pushed through it with the handle on its near side, and the shaft projecting toward the wall. Two wooden pins driven through the shovel handle, one on either side of the crosspiece, fixed the shovel handle in this position without preventing its free rotation in the hole. At the distal end of the shovel handle and at right angles to it, there was attached a stout lever arm 6 inches long, and from this a weight was suspended. Whereas this machine was devised merely for pronation and supination exercisces by rotating the shovel handle, the roller bearing permitted an adjustment for the height of the man.

We constructed another appliance, similar in every detail to the pronation and supination machine, with the exception that the shaft of the shovel handle moved in a large oval opening, thus giving the handle a wider range of movement.

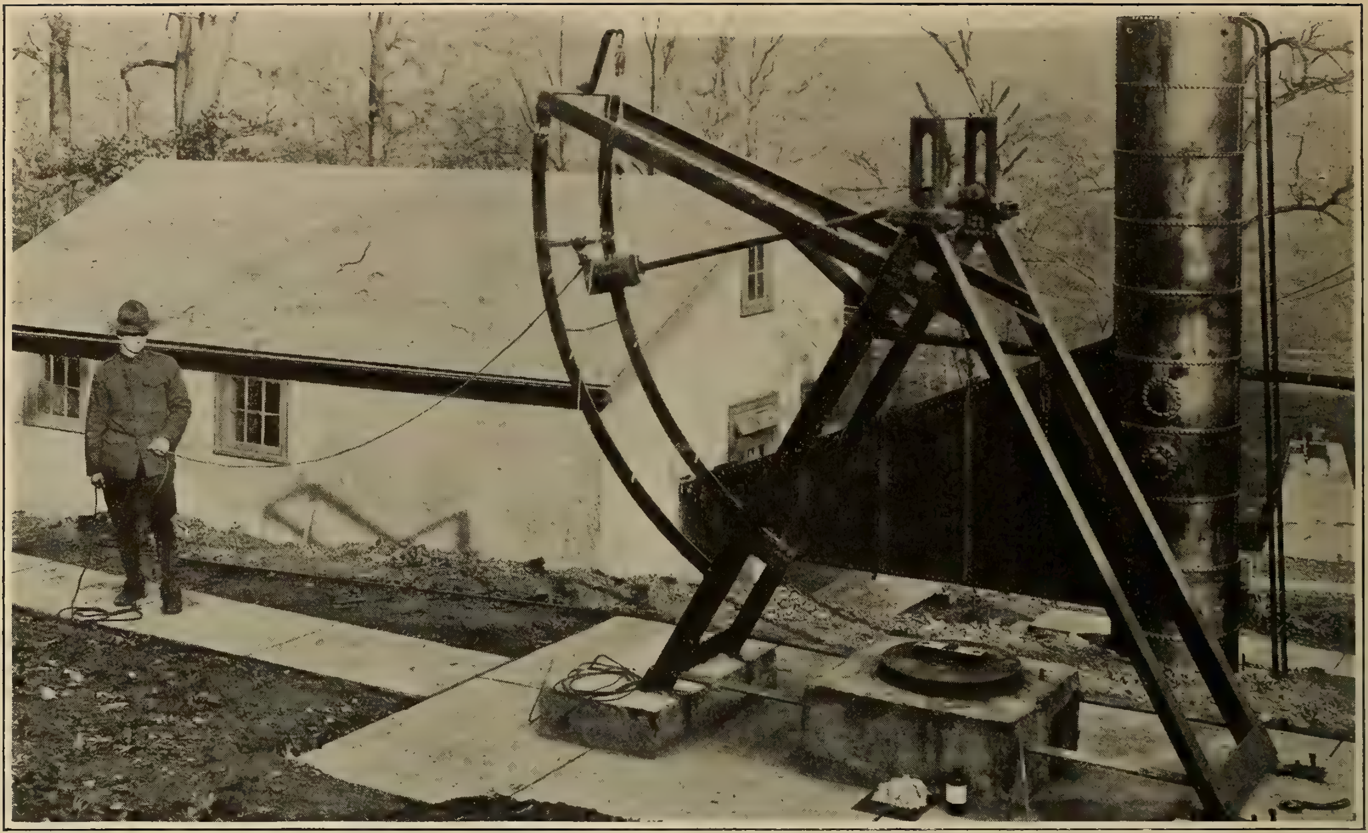
To produce circumduction at the wrist, we mounted a wheel with its axle on a wooden bracket in the same position as the wheel in the shoulder circumduction apparatus, with the exception that the axle was 3 feet high (Fig. 7). The wheel was 12 inches in diameter, and it also was obtained from the reclamation department. A wooden arm support was mounted on a level, with the axle, at right angles to the plane of the wheel, and 12 inches away from it. The arm was fixed to the support by means of straps in such a position that the carpometacarpal joint rested on the edge of the support. The patient grasped a discarded screw driven in his hand, and placing the shaft between the spokes, propelled the wheel. Thus, the desired circumduction was obtained.

APPARATUS FOR GENERAL EXERCISE

For the purpose of obtaining general exercise, a rowing machine was suggested. Two uprights were built to the floor out of two-by-fours 30 inches high, 4 feet apart and 4 feet from the wall. (Fig. 8). Oars were constructed out of two-by-fours, 3 feet long, the ends of which were whittled down for handles. The oars were pivoted to the uprights through their centers by means of discarded motor valve stems. Two pulleys were fastened to the wall at the same height and immediately behind the distal ends of the oars, and two more placed 3 feet above and 6 inches outside of the vertical planes of the lower set. Ropes were tied to the distal ends of the oars and extended through the lower pair of pulleys then through the upper pair to the two shell casings filled with clay as weights. A seat was mounted behind the oars with three footrails in front. Four rollers attached to the bottom of the seat permitted free backward and forward motion on a wooden track. The novelty of this device proved to be quite attractive to the men, and they took great advantage of it.

COMMENT.

The purpose of this brief review of the practical application of well-known scientific principles in the crude apparatus devised will be served if I have been albe to demonstrate the early approach thereby to the larger field which concerns us now as orthopedic surgeons, namely, the application of the principles of vocational training and re-education to the wounded soldiers returning to our reconstruction hospitals. It is believed that the success attained in the service at Camp Cody will be encouraging to those who may be called on to make an effort at rehabilitation in centers where modern means of vocational training may not be readily available.



ABOUT TO RELEASE THE SWINGING SHOE OF THE PENDULUM FRICTION APPARATUS

A Pendulum-Type Testing Apparatus*

Testing Potassium Chlorate Explosives at the U. S. Bureau of Mines

By S. P. Howell

It has long been known that many commercial explosives may be exploded by severe and prolonged friction. It is also well established that some explosives are more sensitive to friction than others.

Certain kinds of potassium chlorate explosives have long been regarded as very sensitive to friction, as evidenced by the following quotations from Berthelot, Gody, Dupré, and Brunswig. Berthelot says:[1]

"Berthollet, after having discovered potassium chlorate and recognized the oxidizing properties so characteristic of this salt, thought of utilizing it in the manufacture of service powders. He made several attempts in this direction, but immediately suspended them after an explosion which happened during the manufacture carried on at the Essonnes powder factory—an explosion in which several persons were killed around himself. The same attempt has been revived at various periods, with certain variations in the composition.

"But in every case explosions, followed by loss of lives—such, for instance, as those which happened during the siege of Paris in 1870 and at L'Ecole de Pyrotechnie in 1877—happened before long in the course of its manufacture.

"It is thus clear that potassium chlorate is an extremely dangerous substance, which is only natural, because its mixture with combustible bodies is sensitive to the least shock or friction."

Gody says:[2]

"Berthollet missed losing his sight from the explosion of a chlorate explosive during imprudent manufacture in a mortar. . . .

"The mixture of combustible material with potassium chlorate must be made with the minutest precautions, as the least shock or friction may cause an explosion."

Dr. Dupré, as cited by De Kalb,[3] says:

"Chlorate of potassium, on account of the readiness with which it lends itself to the production of powerful explosives, offers a great temptation to inventors of new explosives, and many attempts have been made to put it to practical use, but so far with very limited success. This is chiefly owing to two causes. In the first place, potassium chlorate is a very unstable compound and is liable to suffer decomposition under a variety of circumstances, and under comparatively slight causes, chemical and mechanical. All chlorate mixtures are liable to what is termed spontaneous ignition or explosion in the presence of a variety of materials, more particularly of such as are acid, or are liable to generate acid; and all chlorate mixtures are readily exploded by percussion, such as a glancing blow which might easily and would often occur in charging a hole. In the second place, there is some evidence to show that the sensitiveness to percussion and friction increases by keeping, more especially if the explosive is exposed to the action of moist and dry air alternately."

Brunswig,[4] a more recent authority, in speaking of chlorate powders says:

"These powders have received little attention on account of

*Technical Paper 234, U. S. Bureau of Mines.

[1]Berthelot, M.P.E., Explosives and their power, translated by C. N. Hake and William Macnab, 1892, p. 518.

[2]Gody, L., Traité théorique et pratique des matières explosives, 3rd ed., 1907, p. 240.

[3]De Kalb, Courtenay, Manual of explosives, 1900, p. 16.

[4]Brunswig, H., Explosives, translated and annotated by C. E. Munroe and A. L. Kibler, 1912, p. 302.

their greater sensitiveness toward shock and friction. In more recent times, however, the preparation of chlorates and perchlorates by electrical methods has made these substances easy to obtain, and it has been discovered that the addition of fatty oils to chlorate mixtures decreases their sensitiveness.

"Various annual reports[5] of His Majesty's inspectors of explosives, Great Britain, record fires and explosions with various potassium chlorate explosives during the operation of sifting, mixing, ramming with wooden rammers, and ramming with bronze rammers."

A certain potassium chlorate explosive that is used in the United States and is designated "Chlorate explosive B" in this paper has come under suspicion because of premature explosions that occurred while it was used in bituminous coal mines. The details of these accidents are as follows:

1. While inserting copper needle in a charge in a tamped bore hole the charge exploded. Miner not injured.

2. This accident occurred less than one hour after accident 1, but in another room of the mine. The charge exploded while the copper needle was being inserted in the charge in a bore hole. Miner not injured.

3. While pushing a 12-inch cartridge into bore hole, with copper needle inserted about 6 inches in it, and just before charge reached back of bore hole, the charge exploded. Miner severely burned and hand badly lacerated.

Other potassium chlorate explosives containing potassium chlorate and sugar also exploded prematurely in coal mines in the United States. The details are as follows:

4. A 7-inch by 1-inch charge had misfired in a 5½-foot bore hole, presumably on account of using wet squibs. The stemming was then drilled out about 3 feet and copper needle inserted to reform the needle hole. The needle went into the clay stemming easily and the miner "did not have to exert any strength to force it." He was turning the needle around to form the hole for the squib and just as the needle went through the stemming it turned to go a little bit faster, then the shot went off prematurely. The miner lost the thumb and index finger of his left hand, besides being lacerated about the chest and arms, and his face was slightly cut.

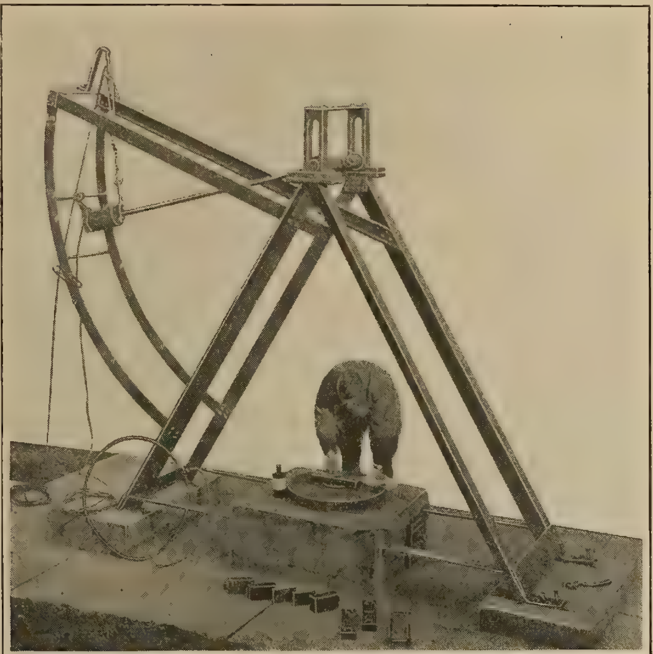
5. While a miner was tamping several inches of stemming on the explosive it exploded. No injury reported.

6. After putting in several handfuls of stemming on the explosive it exploded. The cartridge had been broken when being inserted. No injury reported.

7. Exploded while pushing the copper needle into the explosive. No injury reported.

In view of the frequency of these accidents and the seeming ease with which they took place, not being explanable by the sensitiveness of the explosive itself to friction, it was considered advisable to determine, if possible, the cause of the excessive sensitiveness to friction.

As the coal in the mines in which these accidents occurred contains pyrite-bearing bands, it was thought that the pyrite might be a general cause of the accidents, as practically all bituminous coals, and especially those of the Middle West have these pyritiferous bands.



PREPARING FOR A TEST WITH THE PENDULUM DEVICE

At the suggestion of Clarence Hall, chief explosives engineer of the Bureau of Mines, the experiments described below were made to determine the effect of pyrite-bearing coal on sensitiveness to friction of potassium chlorate explosives.

Chlorate explosive B, which failed to pass the pendulum friction test with the wood-fiber shoe dropped from the 1½-meter position, gave no unfavorable results in 10 trials when the wood-fiber shoe was dropped from the 1-meter position. Under the same conditions, but mixed with small pieces of pyrite-bearing bituminous coal, the explosive ignited in each trial. It was found also that ignition occurred when the height of fall was reduced to ½ meter and even to ¼ meter.

Similar tests made with FFF black blasting powder and 40 per cent nitroglycerin dynamite gave no ignitions.

In order to determine whether the friction of a moving copper-wire needle in a bore hole would be sufficient to cause an ignition of chlorate explosive B, the following test was made.

A hole one-half inch in diameter and 4 inches deep was drilled in a block of bituminous coal. A 2-gram charge consisting of 4 parts of chlorate explosive B, 1 part coal dust, and 1 part pyrite of the same granulation as the explosive was placed in the bore hole. The friction from the movement of a No. 8 (B. & S. gage) copper needle within this mixture caused ignition.

Repeated with three other chlorate explosives of the same general type, this test gave the same results.

Similar tests with FFF black blasting powder and 40 per cent nitroglycerin dynamite gave no ignition.

An unpublished report by Russell B. and Treadway B. Munroe, which was available to the Bureau of Mines, on the effect of metallic sulphides on a sodium chlorate explosive showed that both antimony and lead sulphides increased the sensitiveness of the explosive to friction more than pyrite.

This conclusion is in part corroborated by the work of Cushman,[6] who shows that in priming compositions the compositions containing antimony or lead sulphides are more sensitive to impact than the composition containing pyrite.

To determine the sensitiveness of potassium chlorate explosives, the English have long used the broomstick test. This test consists in spreading a small quantity of the explosive on a soft wood surface and striking it a glancing blow with a broomstick. An explosive is considered as having passed this test if it fails to explode or crack when tested repeatedly.

A rawhide-mallet test has been used at the Bureau of Mines and elsewhere to determine the sensitiveness of explosives. A small portion of the explosive is spread on a smooth oak surface and struck a glancing blow with the mallet. The explosive is considered as having passed this test if there is no explosion or local crackling.

Obviously the broomstick test and the rawhide-mallet test lack the uniformity in execution that should characterize a scientific friction test, so in June, 1911, the Bureau of Mines

[5]32d annual report, 1907, pp. 114, 122; 33d annual report, 1908, p. 95; 34th annual report, 1909, p. 104; 36th annual report, 1911, p. 109.

[6]Cushman, A. S., Antimony sulphide as a constituent in military and sporting arms primers; *Jour. Ind. and Eng. Chem.*, vol. 10, 1918, p. 376.

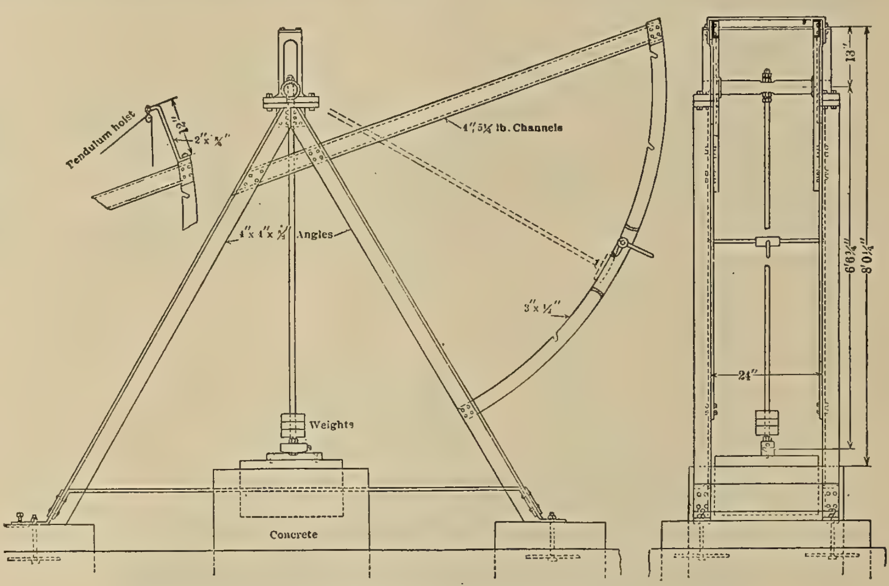
designed a pendulum friction device. The first tests with it were made in September, 1911. Tests of a variety of explosives, including permissible explosives, commercial explosives other than permissibles, black blasting powder, and potassium chlorate explosives, showed that all explosives except a certain potassium chlorate explosive passed the test.

In October, 1911, a committee consisting of Dr. C. E. Munroe, C. P. Beistle, and Clarence Hall was appointed to pass upon the propriety of the pendulum friction test as a requirement for determining the permissibility of explosives for use in coal mines.

After studying the results of the preliminary tests, and witnessing tests of the pendulum friction device provided with a wood-fiber shoe, the committee recommended the adoption of the test. Their report was approved by Director J. A. Holmes on November 22, 1911.

In the opinion of the director and the committee, the failure of an explosive to pass the pendulum friction test as adopted by the Bureau of Mines should be considered an unfavorable physical characteristic because of the liability of such an explosive to explode in drill holes, by such friction as may be produced by a tamping rod. Moreover, they decided that the Bureau of Mines was not warranted in placing on the permissible list any explosive that failed to pass the pendulum friction test, but did pass other required tests.

The pendulum friction device adopted by the Bureau of Mines comprises a steel anvil and a swinging shoe. The anvil has a smooth face, 3.25 inches (8.3 cm.) wide by 12 inches (30.5 cm.) long, in the middle of which are three grooves for holding the charge of explosive. The shoe is 3¼ inches (8.3 cm.) wide, its radius of swing is 6 feet 6.75 inches (2 meters), and the radius of curvature of its face is 10.5 inches (26.7 cm.). The shoe may be of steel, or of steel faced with hardwood fiber or other material, and may be dropped from heights up to 78.7 inches (2 meters). Added weights of 2.2 to 44 pounds (1 to 20 kg.) may be used.



ELEVATION AND DETAILS OF THE TESTING MACHINE

In the official test adopted by the Bureau of Mines a steel shoe faced with hardwood fiber, 44 pounds (20 kg.) added weight and a fall of 59.1 inches (1.5 meters) are used. The shoe is squarely adjusted so that when there is no explosive on the anvil it will swing across the face of the anvil 18±1 times before coming to rest.

In making the test 7 grams of the explosive is spread in an even layer in and above the three grooves in the anvil. Each test consists of 10 trials. After each trial the remaining explosive is brushed from the anvil and shoe, and both are thoroughly cleaned with a solvent to insure the complete removal of the explosive. When the steel shoe is used, both the shoe and anvil after each trial are rubbed with carborundum cloth to remove any roughness caused by the preceding trial; thus any gritty material is thoroughly removed.

The usual tests are made at normal temperatures (14° C. to 30° C.), the temperature of the anvil and of the shoe being controlled.

The observations made are explosion, whether complete or partial; burning; local crackling, whether distinctly audible or almost indistinguishable; and no local crackling. An explosive that gives no more unfavorable result than an almost indistinguishable local crackling with the wood-fiber shoe is considered as having passed the test.

As soon as tests showed that the steel shoe was more severe than the wood-fiber shoe, explosives were first tested with the steel shoe and usually were not tested on the wood-fiber shoe if they passed the test with the steel shoe. (*The Bulletin contains a number of tables which are omitted.*—EDITOR.)

SUMMARY OF RESULTS.

1. Tests with the steel shoe are much more severe than tests with the wood-fiber shoe.

Forty per cent straight dynamite passed the test at 2.0 meters fall and 20 kilograms added weight with the wood-fiber shoe, but failed with the steel shoe at 0.5 meters fall and 20.0 kilograms added weight, and 1.5 meters fall with no added weight. Moreover, the record shows that 40 explosives failed under test with the steel shoe but passed the test with the wood-fiber shoe, but for no explosive was the reverse true.

2. All the explosives tested with the wood-fiber shoe passed the test except 10 potassium - chlorate explosives and one perchlorate explosive.

3. Of 267 samples tested with the steel shoe, 55 failed to pass the test.

4. Black blasting and ignition powders, blasting gelatin, ammonia dynamites, and organic nitrate explosives (other than nitroglycerin) are not as sensitive to frictional impact as the nitroglycerin dynamites and the gelatin dynamites.

5. TNA, tetryl, 50/50 amatol, and 60/40 sodatol are more sensitive to frictional impact than TNT, picric acid, ammonium picrate, 85/15 amatol, 80/20 sodatol.

6. Tests of TNA, and of 40 per cent straight dynamite with the steel shoe, show that increasing the height of fall increases the severity of the test.

7. Tests of 40 per cent straight dynamite with the steel shoe show that decreasing the added weight decreases the severity of the test.

8. The tests at normal and high temperatures showed that no discrimination can be made on the basis of increasing the temperature.

9. Potassium chlorate explosives have proved extremely sensitive to frictional impact even when the wood-fiber shoe is used. But some were rendered sufficiently insensitive to friction by adding an adequate quantity of mineral oil, vegetable oils, and aromatic nitro compounds.

10. That the pendulum friction device, as adopted by the Bureau of Mines, is not too severe is indicated by the fact that one of the potassium chlorate explosives which passed the test has on more than one occasion exploded prematurely during manufacture and use. On the other hand, potassium chlorate explosives of the general type of E (potassium chlorate, sugar and gum arabic) which failed to pass the pendulum friction test exploded prematurely on several occasions in use.

11. The sensitiveness of potassium chlorate explosives to friction is increased by the presence of pyrite-bearing coal.

Luminous Living Creatures*

The Mystery of "Cold Light"

By Dr. Raphael Dubois, Prof. of General Physiology, University of Lyons

LIVING creatures produce not only motion, heat, and electricity but also light, more or less vital in character, and the glow worm with which all the world is familiar has by no means a monopoly of this manufacture.

In every part of the globe, in the air, in the woods and meadows, in the bosom of the waters, there are living signal lights gleaming with strange and shimmering fires, which are incomparably beautiful and suggestive, not only in the eyes of the poet but even more so in those of the savant, for the scientific researches which have been undertaken in the hope of plucking from nature this marvellous secret of hers are numbered by thousands. Upon the surface of the ocean, sometimes over immense extents, the sea shines with a splendor that rivals the starry firmament, while in the depth of its abysses fairy illuminations suddenly blaze forth among the forests of polyps at the passage of fantastic animals, which are themselves wreathed with shining gems, the strange brilliance of whose fires would put to shame the most sumptuous jewels.

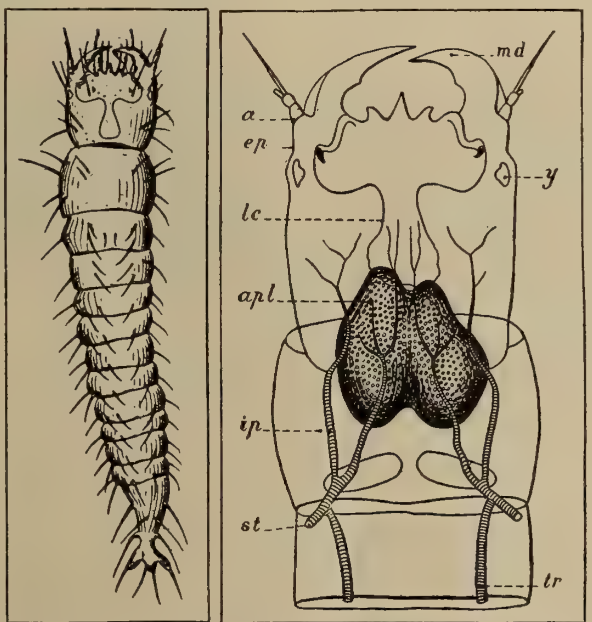
A GROUP OF PHOTOBACTERIA OR LUMINOUS MICROBES

Plants also produce light. In the gloomy galleries through which the miner, ever on his guard against the deadly fire damp, bears his dim and dangerous candle, the myceliums of fungi shine upon old worm eaten beams with a calm, pale, harmless, moonlight gleam. It is these vegetative organs of fungi, also, which in the forests produce the phosphorescence of dead wood and leaves and old stumps. Adult fungi, such as the Agaric of the olive, which is common in Provence, likewise shine in the dark. In Brazil and in Australia the emerald green light of other species is so bright that one can easily read a newspaper or see the time on a watch dial by means of this living torch.

Most extraordinary are those infinitely small fungi, the luminous microbes or Photobacteria. Some thirty species of marine origin are known. They are particularly abundant in the mucus of the skin of sea fishes, but their phosphorescence does not develop, however, until from twenty-four to forty-eight hours after the animal has been taken from the water. It is readily communicated by microbian contagion to butchers' meat. The latter often becomes luminous when it is merely exposed to the air after having been moistened with salt water. The phosphorescence is continuous but is scarcely visible except at night when the eye is rested from the light of day. The first phosphorescent microbe of meat which has been isolated and cultivated in the pure state is that to which I have given the name of *Photobacterium, sarcophilum.* The ingestion of these microbes is not at all dangerous; the frog can never be inoculated with them with impunity, as I long ago demonstrated. The same thing is not true, however, of certain small crustaceans (shrimp, prawns, sea fleas, wood lice), which become entirely luminous after inoculation but soon perish. Gnats and mosquitos sometimes exhibit this luminous malady spontaneously and it might be possible to attempt to destroy by this means these creatures which propagate harmful germs like that of malaria.

I have found non-pathogenic luminous microbes in the interior of the organs of certain animals which are themselves phosphorescent. However, those persons who pretend that these are normal or *symbiotic* microbes which produce physiological animal light have incorrectly interpreted my observations. A very curious circumstance, however, is that when inoculating with photobacteria gelatinous bouillons containing lecithine I have provoked the formation of luminous cells much resembling those of the glow worm in certain respects. They are formed by the agglomeration of a multitude of photobacteria which have lost their bacterial form and become transformed into very small micrococci. The photobacteria are very polymorphous and very polybiotic, which has led some authorities to multiply the species without justification. There are some forms which are immobile and others which move by means of propulsive cilia. In their internal structures these forms resemble the *vacuolids* or microleucites which I have described as being the most simple general form of living substance or *bioproteon.*

The luminous microbes are easily cultivated in liquid or gelatinous nutritious bouillon containing three per cent of salt, by coating the inside wall of large, sterilized glass casks with gelatinous bouillon which had been planted with selected photobacteria, I was enabled in 1900, at the International Exposition of Paris, to illuminate as with the most beautiful moonlight the underground chambers of the Palace of Optics. It was upon the same principle that I constructed my *living lamp.* This is composed of a convex glass vessel whose silvered dome serves as a reflector and into which filtered air passes through cotton wool inside of two aeration tubes. With this little night lamp which will last a month without going out and without consuming more than two cents worth of fuel, one can easily read in the dark or distinguish the objects in a room. Moreover, it is very portable and cannot set anything on fire since it radiates only *cold light.* Unhappily I have not as yet been able to impart sufficient intensity to this method of illumination. At the present time this lamp has scarcely any possible practical ap-



LARVA OF *PYROPHORA NOCTILUCA* AND ITS LUMINOUS APPARATUS

Md. = mandibles; *a* = antennae; ep = epistome *y* = eye; *le* = clear line; *apl* = apparatus producing light; *ip* = insertion of first pair of legs; *st* = level of first stigmata; *tr* = trachea.

*Translated from *Science et La Vie* (Paris).

plication except in powder mills in mines where fire damp is feared, or as a night lamp in those hot countries where even the gentle heat from an incandescent electric light is annoying. The light of this lamp is more feeble than that of the illuminating apparatus of insects, of cephalopods, or of certain fishes, in spite of the fact that it is a result of the same reaction; but the luminous organs of these animals are provided with improvements which greatly augment their brilliance. When these organs are crushed they do not shine, unfortunately, with any more brilliance than do the microbes.

MODEL OF THE *GIGANTACTIS VANHOEFFENI*, A DEEP SEA FISH WHICH CARRIES A LUMINOUS TORCH AS A LURE TO ITS PREY

Luminous animals are found in almost every degree of the zoölogical scale from the Noctiluca, the microscopic infusoria which produce the magnificent and impressive spectacle of the phosphorescent sea, up to and including the vertebrates. In the bosom of the ocean numerous photogenic Coelentera undulate gracefully like animated flowers made of the purest crystal—Medusas, the cestus or girdle of Venus, the Physalia with their numerous fishing tackle, while upon the surface there float flotillas of light Velellae with their triangular sails, etc., etc.

Upon the bottom of the sea and even at the bottom of the abysses there grow the Polypidae, actual luminous shrubs whereupon the polyps resemble gleaming flowers with changing colors which glow with light at the slightest touch.

Then there are the starfish, like the Brisinga which derive their appellation from "Brising," the name of the sparkling jewel which rested upon the bosom of Freia, the goddess of love and beauty in Scandinavian mythology. Quite close at hand in our own gardens we often see at night time the earth worms and the "thousand legs" leaving behind them trails of phosphorescent mucus, and in south Germany I have seen the ground sprinkled with shining sparks like the sand of our beaches, thanks to the presence of the little *Lipuris noctiluca*. But it would require a volume to describe all these curious shining animals, for they are legion.

Among the crustaceans, the Cephalopod mollusks, and the fishes the luminous organs are often situated near the eyes or around them in such a manner as to illuminate clearly the objects which they desire to see. They are then provided with lenses, reflectors, screens, etc., which make of them perfected lanterns called "photospheres."

Although less complicated than these photospheres the lanterns of the insects are very brilliant. That of the female glow worm can be distinguished for a long distance. But nothing can equal in power and in beauty the signal lights of the Pyrophora of the Antilles. This sturdy and magnificent *taupin* possesses three of these—two upon the corselet and one underneath the abdomen. It makes use of the first two when walking, of the third when swimming, and of all three at the same time when flying. These beautiful insects produce a very strikinng effect when they fly along the edge of the woods or sugar cane plantations in the eveninng. One of them which arrived at Paris with some wood from these islands in September, 1766, produced quite a little revolution in the Faubourg St. Antoine, where it was taken for a shooting star! The author of *The History of the French Antilles* (*Histoire des Antilles française*) P. Dutertre, wrote in 1667: "They are like little animated stars which in the darkest nights fill the air with an infinity of beautiful lights which shine and gleam with more brilliance than the stars in the heavens. . . . These little candles often relieve the poverty of our good fathers who lack both oil and candles for the greater part of the year. When they are thus reduced each of them grasps one of these shining flies and reads his matins with as much ease as if he had a candle." Then he adds further: "If these flies were incorruptible like precious stones and could retain their light it is certain that diamonds and rubies would lose their value." It is not astonishing, therefore, that the beautiful Mexican ladies keep these little creatures captive to make of them living adornments.

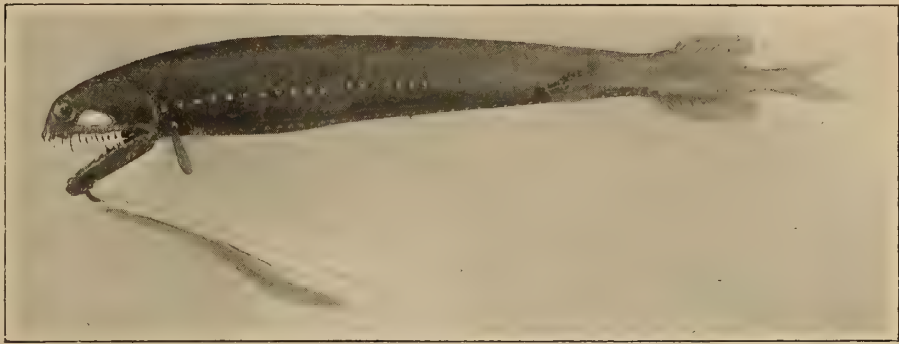
When the New World was discovered the Indians enclosed them in perforated gourds hung in their cabins, both to light them by night and to drive away snakes and mosquitos. In time of war they made use of these signals which are extinguished neither by rain nor wind to carry on a sort of optical telegraphy, of which art they are thus the real inventors. It was these sturdy coleopetera, of which I received a number of living specimens from Guaduloupe when I was a preparer for Paul Bert at the Sorbonne, which enabled me to make a complete anatomical and physiological study, thus discovering the secret of the intimate mechanism of their curious lanterns and obtaining a definite analysis of the physical properties of their beautiful light. In the very heart of Paris I have seen them lay their luminous eggs from whence issued larvae likewise luminous, so that in the case of these extraordinary insects, as in so many other photogenic animals, phosphorescense is transmitted like the flame of life itself without ever being extinguished for a single instant from generation to generation throughout the ages.

MODEL OF THE *OPISTHOPROCTUS SOLCATANUS*

The molluscs likewise afford curious specimens. The *Euno-ploteuthis diadema* is a cuttle fish caught at a depth of 1,500 meters. It is provided with 24 lanterns, five of which are situated around each of the two eyes. These give forth a light of the most incomparable beauty. One might imagine the body of the animal adorned with a diadem of precious stones of varied color and of the finest water. The median points

shine with an ultramarine blue, while the lateral ones show the tints of mother of pearl. The abdominal organs send forth rays of ruby red, while the posterior ones are white as snow or pearly in tint, with the exception of the median point which shines with a celestial blue. But it is only among the fishes that we find organs so highly complicated. The *Stomias* present a double row of them on each side of the body, as does the curious *Stylopthtalmus paradoxus* which also possesses lantern eyes borne upon long movable tentacles.

MODEL OF THE *MELANOSTOMIAS MELANOPS* STUDDED WITH LIGHTS WHICH



LOOK LIKE PORTHOLES OF A SHIP AT NIGHT

In the Melanocetus of the abysses the signal-light is placed at the end of a movable wattle, and probably serves as a lure to attract within the huge and well-armed jaws of the little monster the organisms upon which it commonly feeds. In other cases, as in the *Photoblepharon palpebratus*—a surface fish of the Dutch East Indies, whose fishermen utilize the luminous apparatus as bait—the signal-lights are situated below the eyes and are movable like the latter, which enables the animal to mask them whenever it so desires.

MODEL OF THE LUMINOUS DEEP SEA FISH *BARATHRONUS DIAPHANOUS*

Apparently phosphorescence does not exist among vertebrates higher in the scale than the fishes. The cases in which luminosity is exhibited by cadavers, by wounds, by sweat, by urine, and by excrement are pathological in nature and call for more extended study. In all cases of organisms which are normally luminous the photogenic organs, when they are differentiated, consists of glands, which discharge either outwardly, as, in the earthworm and the wood-louse or "thousand legs," or else internally, as in the fishes, the cephalopods, and the insects, their magnificently luminous secretion.

The ventral photogenic organ of the *Pyrophorus noctilucus* is a type of the internal secretion luminous gland. It is in the form of a cushion traversed by a sinus at T. At the instant when it functions the small lateral muscles draw apart by means of traction the walls of the sinus, into which the blood at once rushes, causing the instant appearance of the light. The muscles are activated by nerves coming from certain nerve centers and it is by means of these that the reflex or voluntary contractions which control the illumination and the extinction of the light are operated. The gland is constituted of rows of cells whose disintegration yields the liquid of the luminous secretion, which, upon contact with the oxygenated blood, produces the light, by a process which will be explained further on. The trachea, which are abundant in these organs, play merely an accessory part, for they do not appear in the egg, which is luminous nevertheless, nor in the analogous apparatus of the cephalopods and the fishes. Doubtless the trachea serve here as elsewhere to aerate the blood, an especially important operation in this instance.

If the luminous organ be crushed in a little water so as to entirely destroy all trace of cells a liquid is obtained which remains luminous for a considerable length of time, but which is instantly extinguished by any physical or chemical agent capable of destroying the zymases and the proteic substances. When filtered this luminous liquid is opalescent—like all colloidal solutions—and contains very fine granulations which are termed zymasic *vacuolids*.

As early as 1886 I succeeded in demonstrating the fact that in the last analysis the luminous phenomenon results from the conflict between two substances, a zymase and a proteic substance, which exhibits, after the action of the zymase, the xantic reactión of nitrogenous organic bodies. This had to be made more definite—but Pyrophoras were lacking, and furthermore their provision of luminous substance is much too scanty for extensive chemical research. I turned my attention, therefore, to a lamellibranch Mollusc, the dactylated Pholas, which is abundant in the vicinity of the maritime laboratory of physiology founded by me at Tamaris-sur-Mer, near Toulon. The photogenic glands of this shell-fish secrete an abundance of a luminous mucus which exhibits the same reactions as the secretions of all other luminous organisms, in which the fundamental nature of the photogenic process is always the same. Not without great difficulty and repeated efforts, I was finally able to extract, isolate, and determine the chemical characteristics of two principles which I have termed respectively *luciferase* and *luciferine*. The first is an oxidizing zymase, while the second is a natural

THE *STYLOPHTHALMUS PARADOXUS* WITH LANTERNS AT THE ENDS OF TENTACLES WHICH MAY BE EXTENDED OR RETRACTED AT WILL

albuminoid. When either of these is shaken separately in contact with air and with water no light appears, but upon mingling the two aqueous solutions a very beautiful glowing light is at once produced. But if the water is saturated with sugar the two solutions can be mingled without producing light, since this condition paralyzes the action of the oxidizing zymase. The syrup can be kept quite a long time without undergoing alteration, but as soon as water is added the luminous glow appears; the glass in which the reaction takes place can be used for a night lamp. . . .

The luciferase can be replaced by various oxidizing chemical substances, a fact which clearly indicates its mode of action; among these are permanganate of potash, broxide of lead, hydrogen peroxide containing a little blood or hermatine or simply a ferric salt, etc., etc.

Synthesis follows upon analysis—the former would be complete if we could manufacture luciferine artificially. However this is not necessary to occasion the appearance of cold light in a liquid medium by means of oxidation. These phenomena of "oxyluminescence" are even quite numerous, but the most beautiful of all is that which I have obtained with esculine, a fluorescent chemical principle extracted from the chestnut tree.

Now that its principle is known, it is possible therefore to imitate "living," or rather physiological light. It must be admitted that the light obtained *in vitro* is not so powerful as that from the lantern of the Pyrophora, in spite of the fact that the chemical process involved is the same. But, as we have seen in the foregoing remarks, these insects, like the cephalopods and the fishes, possess accessories which make for improvement. One of the most curious of these is that discovered by me in 1885; it consists of the presence of a fluorescent substance in the luminous organs of the Pyrophora and of the Luciola: this is a *luciferescein* whose effect is the transformation of the dark rays, which are both useless and injurious, into illuminating rays, which superpose themselves upon the fundamental photogenic reactions, just as sonorous harmonics or overtones superpose themselves upon the fundamental note of a sound. It is in this manner that sounds acquire an agreeable *timbre*, and in the same way fluorescence imparts to the light of the Pyrophora a shimmering effect of the greatest beauty, while at the same time much augmenting its power.

It is thanks to the Pyrophora that it has been possible to make a complete and authoritative analysis of the physical properties of physiological light. Its enormous superiority over that of all other known sources of light, including the sun itself, has become a classic fact, today, and the correctness of the results already published by us has only been confirmed by the latest researches of physicists of the highest ability, such as MM. Very and Langley in America.

It is incontestably established today that this living or physiologic light may properly be called *cold light*, since the radiations emanating from the photogenic organs contain only infinitesimal amounts of heat. If we add that the actinic power of the visible and ultra-violet radiations whose presence I have demonstrated scarcely exceeds one ten-millionth part of a candle power we may claim that the work done by this marvelous lamp is almost 100 per cent, while with the most improved quartz mercury lamp not more than one per cent of light is obtained, according to the extremely exact calculations of MM. Fabry and Buisson, the rest of the energy expended being consumed in the production of heat and chemical energy, which are always inconvenient and sometimes actually injurious. Let us remind the reader also of the extremely low price of my living lamp which will light a room as with fine moonlight for a month for but two cents.

Gas with its necessary pipes and its accompanying dangers of fire and of asphyxiation, and electricity with its wires and its non-transportable apparatus, as well as our lamps and candles, are destined to disappear, since the process by which physiologic light produced is now perfectly understood and classed among the oxy-luminescences, why may we not hope that the day will come when we shall be able to imitate and even to surpass that made by natural means? We are certainly far nearer the practical solution of the problem than were Galvani and Volta at the time of their immortal discoveries.

[*We are indebted to the American Museum of Natural History for the photographs illustrating this article.*—EDITOR.]

The Effects of Light on Plants*

Light As a Catalyzer

By San. Rat Dr. Fritz Schanz

MAN has undoubtedly recognized from the very beginning that light is an essential factor in life. Light acts upon living cells as a chemical stimulus. We recognize this by the reactions which it occasions in living tissues. The chemical alterations which it thus produces have been known to us only very recently. The first insight into the effects light exerts upon the living organism was vouchsafed to us when Finsen proved that the alterations of the skin which occur when the latter is exposed to intensive light waves are produced chiefly by the rays of short wave length which the human eye is incapable of perceiving as light—the rays which we term ultra-violet because they lie beyond the violet end of the spectrum. By means of such rays Finsen produced reaction in the skin through which certain *loci* of disease are destroyed. The fact thus demonstrated that light could be employed as a curative agent, induced physicians to study more extensively the effects of light upon the human organism. Their zeal along this line was increased when it was shown, particularly through the researches of Bernhard[1] and Rollier[2], that internal maladies likewise can be favorably influenced by sunlight in spite of the fact that their loci cannot be reached by direct radiation.

Our knowledge as to the effects of light upon living organisms was still further materially advanced by Van Tappeiner[3] and the students under him. It was observed by them that infusoria contained in certain dyestuffs perish when the latter are extremely dilute, while they frequently remain alive in much higher concentrations of the same substances. The cause of this appeared to depend upon whether light was acting upon the infusoria. This effect was termed *photo-dynamic* by von Tappeiner and was demonstrated in the case of eosin, erythrosin, and a great number of other dyes. A condition of such action appeared to be the fluorescence of such substances. It was also found that toxins, ferments, and similar substances derived from animal and vegetable organisms are destroyed by light under similar conditions; furthermore, the cells of higher organisms (red blood corpuscles, ciliated epithelium) can be seriously injured in this manner. It is possible, likewise, to make warm blooded animals including even men highly photosensitive by such means and thus injure them so greatly in a brief period of time by means of exposure to light that they

*Translated for the Scientific American Monthly from the *Biologisches Zentralblatt* (Berlin).

[1] Heliotherapie im Hochgebirge, Verlag von Emke in Stuttgart 1912.

[2] Korrespondenzblatt Schweizer Aerzte (Journal of Correspondence of Swiss Physicians) 1904, no. 12.

[3] Strahlentherapie Bd. 2 (The Art of Healing by Radiation, Vol. II).

die, exhibiting symptoms of sunstroke or heatstroke. Such substances act only in the presence of light, having no effect in the dark. This action is not due, however, as might be supposed to the formation by the light of a poisonous substance. Such media may be exposed to light for a long time without increasing their toxicity; the injury is occasioned only by the coming together of the light and the dyestuff in the organism.

I have myself obtained further evidence in regard to this question by my researches concerning the light reaction of albuminous bodies (Pflueger's Arch. f. Physiol. 1916 Bd. 164). I was induced to undertake these investigations by my studies with respect to the effect of ultra-violet rays upon the eye. The human retina is not capable of perceiving these rays directly. Under certain conditions, however, they are capable of producing severe inflammations in the eye, e. g., when one travels from the lowlands to a high mountainous region or when the eye is exposed to the intensive light of an electric lamp. Such inflammations are known respectively as snow blindness and electrical ophthalmia. They are caused however, only by the extreme outer ultra-violet rays. The inner ultra-violet rays which are also contained in the daylight found at low levels are not capable of producing such inflammation. The boundary limits of the inner and outer ultra-violet rays must be sought between λ 320 and 300 $\mu\mu$ I put the question to myself as to the effect produced upon the eye by the inner ultra-violet rays. These rays are absorbed by the lens of the eye, which fluoresces actively under their action. How does it happen that we are not able to produce any reaction in the lens with these rays? Do these rays have no stimulating action upon the lens, or, is the lens incapable of reacting to this stimulus? The latter hypothesis is correct. The lens contains neither nerves nor blood vessels. It lacks the necessary apparatus for producing a reaction. However, we find that an alteration is produced in the lens and this alteration, which gradually increases in the course of years, consists in the fact that less easily soluble albuminous bodies are created at the expense of more easily soluble albuminous bodies. In my opinion this alteration of the albuminous bodies is the effect directly produced by the light upon the albumen, which the light reaction compensates in other tissues. Since no reaction takes place in the lens to compensate this alteration, its effect is cumulative throughout the whole life and thus, in the course of time, is produced that thickening of the core of the lens which exhibits itself in the normal eye as far-sightedness between the ages of forty and fifty years. When the process continues increased opacity of the lens is occasioned, ending in senile cataract.

I have been confirmed in this view by numerous clinical observations and experiments[4]. I have proved that it is possible to produce regular alterations of conditions by means of light in solutions of the albumen of eggs, of blood serum, and of lenses. *In albuminous solutions which have been dialyzed to the point where they are free from chlorine the easily soluble albumens are transformed by light into more difficultly soluble albumens, and there are numerous substances which influence this process positively or negatively.* This can be demonstrated by precipitating such solutions, after they have been exposed to light for various periods of time, by means of the ammonium sulphate test and the sodium chloride and vinegar test. The longer the samples have been exposed to light the more quickly the alteration occurs. I tried the experiment with seven test tubes which were filled with equal quantities of dialyzed albumen and exposed in a quartz tube. These were exposed respectively to 0, 4, 8, 12, 18, 24 and 32 hours of illumination. At the end of the exposure each test tube was placed in a dark icebox. At the end of the experiment a saturated solution of ammonium sulphate was gradually added in regularly increasing amounts to the test tube. The result showed that the precipitable substance which we term globulin increases in proportion to the length of the illumination.

In another test this same albumen was employed but in this case to every 15 ccm. of albumen 5 ccm. of ¼ per cent. potash lye was added. In this case the substance precipitable by means of ammonium sulphate was diminished in proportion to the length of illumination.

The same alterations were demonstrated by means of the salt and vinegar test.

The addition of 5 ccm. of ¼ per cent. lactic acid to 15 ccm. of the same albumen solution resulted in increased precipitation under increased length of illumination to an extent obvious to the naked eye without the use of a reagent.

If fluorescing dyestuffs such as those employed by von Tappeiner in his experiments be added to the albuminous solution the alteration of the latter can be augmented. Among such substances employed by me were eosin, fluorescin, haematoporphyrin, and chlorophyl. But colorless substances are also able to influence this alteration in albuminous solutions.

What is the reason for this? The first thing which had to be determined was which light rays are the ones to produce the alteration in the dialyzed albumen. At the beginning these solutions were clear and of a pale yellow tint. Consequently they absorbed but very few of the visible rays in the blue and the violet. It was necessary, therefore to seek the specially effective rays in the invisible area of radiation. On this account I tested the albuminous solutions with respect to their capacity for the absorption of light by means of a quartz spectrograph.

The investigation showed that the albuminous solutions which begin to absorb in the blue and violet, as their yellow tint indicates, absorb the ultra-violet light with especial avidity. Hence the alterations which are produced in the solutions by intensive illumination must be attributed to the ultra-violet rays. If we add dyestuffs to the albuminous solution we obtain dyestuff albumens. The science of histology has taught us the intimate relation which exists between dyestuffs and the albuminous bodies. These dyestuff albumens must absorb more light than the ordinary albumens. To the light which they would absorb in any case must be added the rays which are complementary to their color. Hence these dyestuffs make the albumen sensitive to rays which otherwise would not act upon it. We are justified, therefore, in terming these dyestuffs sensitizers.

Let us now examine the action of the colorless substances which also influence the light reaction of the albuminous bodies. I have investigated these likewise with respect to their capacity for light absorption by means of the quartz spectrograph. Among these substances those which most strongly influence the light reaction of the albuminous bodies are those which absorb most strongly in the ultra-violet. In my forthcoming work: *Biochemische Wirkungen des Lichtes* (Biochemical Effects of Light) which will appear as Vol. 170 in *Pflueger's Archiv.* I have represented a number of such spectra. The area of absorption coincides consequently in the case of these substances with that of the albuminous solution. In this instance we cannot speak, therefore, of sensitization. It is probably best to designate these substances as photo-catalyzers.

In this work I have tried to prove that all organic substances appear to be altered by the light which they absorb. I have been able to prove that it is possible to break up organic substances into their elements and radicals by means of light. In the case of colorless substances the effective area of the light resides in the ultra-violet and in those materials which appear to be fast colored by daylight, it resides in the outer ultra-violet rays. The shorter the length of the waves the more capable they are of breaking down the structure of the molecules.

[4] Wirkungen der kurzwelligen nicht direkt sichtbaren Lichtstrahlen auf das Auge. Strahlentherapie Bd. VI, Wirkungen des Lichtes auf die lebende Zelle. Münch. medizin. Wochenschr, 1915, Nr. 19. Die Wirkungen des Lichtes auf die lebende Substanz, Pflüger's Arch. f. Physiologie, Bd. 161. Uber die Beziehungen des Lebens zum Licht. Münch. medizin Wochenschr, 1915, Nr. 39. Wirkungen des Lichtes auf dielebenden Organismen. Biochem. Zeitschr. Bd. 71. Die Lichtreaktion der Eiweisskorper. Pflüger's Arch. f. Physiologie, Bd. 164.

HOW LIGHT AFFECTS THE *ALBUMENS* OF PLANTS

These investigations were conducted in order to study the effect of light upon the human organism. However, light produces far more striking effects upon plants than upon men and animals. If the views above set forth are correct we must necessarily discover analogous effects in plants. The effect produced upon plants by light is most obvious in the process of assimilation. This process is conducted by the chlorophyl grain which consists of the chlorophyl and the colorless struma, the chromoplast. The first is a fluorescing dyestuff and the latter consists of albumen, which we must conceive of as being, like other albumens, sensitive to light rays of short wave length. Timiriazeff and Engelmann[5] assumed that the chlorophyl acts of the colorless struma of the chlorophyl grain as a sensitizer. Since they were not able to prove, however, that the struma itself is sensitive to light, they were contradicted by Josef and Hausmann.[6] The latter authorities held the view that we are here concerned with a photo-dynamic effect and that the chlorophyl alone acts as the conductor of energy.

"No other light-sensitive substratum is required and none in fact is present," says Hausmann. However, my own researches have shown that a second substratum is present and that we must assume it to be sensitive to light. Hence Timiriazeff and Engelmann are correct. The albumen of the grain must be regarded as sensitive to light, and it is sensitized by means of the chlorophyl, for those rays to which it is not sensitive in itself.

But the chlorophyl is not the only substance in the plant cell which is capable of influencing the action of light upon a chlorophyl grain. The cell sap penetrates the chlorophyl grain carrying to it those materials which it requires in the process of assimilation. Among these materials are included certain ones which influence the light reaction in the manner of catalyzers.

SUBSTANCES WHICH ACT AS CATALYZERS.

Thus I find that the organic acids, a large number of which I have tested, act as definite, positive catalyzers. Such catalyzers include not only substances produced by the plant itself but others which are imbibed by the roots, thus we can distinguish between endogenous and exogenous photo-catalyzers. Different substances are produced through the alteration occasioned by light according to the nature of the said substances which come together in the chlorophyl grain. These substances are more or less peculiar to the individual organism. But we must also take into account just here that the light may be composed of rays having different wave lengths and exerting different effects. In the bright colored petals of flowers different rays are effective from those which operate in the foliage. This may cause the formation in the blossoms of peculiar substances which are stored up in the reserves of the fruit and which pass over with the seeds into the new-born organism.

Hitherto the view has been held that the bright colors of flowers were intended as sign posts for insects to point the way to their food. "Bees and flowers! For the understanding mind there is a peculiar charm in the connection of these two ideas. The wide, shimmering, color-bright sea of blossoms and the world of insects which pay their visits thereto have developed side by side in mutual adaptation through the course of long periods of time towards an ever greater degree of perfection!" These words were penned as recently as 1915 by von Buttel-Reepen in No. 7 of *Naturwissen-schaften*. This view is quite erroneous in so far as it concerns the colors of flowers. Von Hess has shown that all insects including bees are color blind. It is true that Von Frisch, on the other hand, has endeavored to prove that bees may possess a limited capacity for discrimination between colors about such as that possessed by a person who is blind to red and green. But even so it is quite clear that the "wide, shimmering, color-bright sea of blossoms and the world of insects destined to visit it,'" have not developed side by side in mutual adaptation. The variegated colors of the flowers could not have been produced to serve insects who are either totally color blind or blind to red and green.

THE MEANING OF COLORS IN FLOWERS

We must seek another explanation for the significance of color in flowers. In my own opinion the colors of flowers act as sensitizers in the same way as chlorophyl in green leaves. They make a different selection among the rays of light and in accordance with such selection peculiar substances are formed which are stored up in the fruit and carried over with the seeds to the new individual. This concept of colors as sensitizers implies that they are highly important with regard to the plants' own needs.

Countless researches have proved that assimilation is occasioned mainly by those rays of the visible spectrum having a long wave length, *i.e.*, those rays to which albumen is not sensitive in itself and to which it must first be sensitized, accordingly, by means of the chlorophyl. The rays of short length appear to take less part in this process in spite of the fact that they are otherwise chemically more effective. This fact caused me to inquire how it happens that the rays of short wave length, especially the ultra-violet rays, play so little part in the assimilation process. In order to answer this question I compared plants exposed to the full light of day with others which were shielded from rays of short wave length. Cuttings of as nearly the same size as possible from the same plant were planted in pots in the same sort of garden soil. The first plant was allowed to grow freely while a large bell jar of Euphos-glass surrounded the second. This glass is yellowish green in color; it begins to absorb light in the blue and violet portions of the spectrum and absorbs the ultra-violet completely. The third plant was covered with a bell jar of ordinary colorless glass. This glass also absorbs a part of the ultra-violet from daylight. The glass bell jars had an opening at the top above which a piece of the same sort of glass was so placed that air could reach the plant but not daylight. The plants were placed side by side and watered with equal quantities of water.

The first of these plants grew freely while the second as we have said was shielded by means of Euphos-glass from all ultra-violet rays and the third was shielded by ordinary glass from a portion of the ultra-violet rays. These experiments were repeated with different plants for many years consecutively, always with the same result. The plant which grew freely exhibited nothing exceptional, while the one under the Euphos glass had grown much larger and somewhat reminded one of an etiolated plant, although it was green; the third plant raised under ordinary glass was also larger than the one grown in the open air. All three plants were grown under the same conditions except for the circulation of air which was naturally less in the case of the plants under the bell jars; naturally, likewise, the use of the bell jars involved a certain increase in temperature. This difference, however, did not exist between the plant placed under the Euphos glass and the one grown under ordinary glass and these two likewise exhibited a marked difference in height. The reason for the difference in form of the plants must be sought, therefore, in the decreased amount of light admitted. Both the Euphos glass bell jar and the one of ordinary glass prevented ultra-violet rays from reaching the plants. This was also shown by the fact that the ash which remained from the incineration of the plants was smallest in quantity in the case of the specimen raised under the Euphos glass. Thus we are obliged to con-

[5] Farbe und Assimilation (Color and Assimilation). Bot. Zeitung, 1883, 20.

[6] Die Photodynamische Wirkung des Chlorophylls und ihre Beziehung zur phoyosynthetischem Assimilation der Pflanze. (The photodynamic Effects of Chlorophyl and its Relation to the photosynthetic assimilation of plants) Biochem. Zeitscher. Bd. xli, S.330.

clude that the *form of plants is altered by light rays of short wave lengths and most of all by the ultra-violet rays.*

It is well known to botanists that the processes of motion in plants are affected chiefly by the rays of short wave lengths while assimilation is chiefly influenced by those of long wave lengths. I have not been able to find any explanation of the reason for this difference in action in the literature to which I have access. I believe, however, that I am capable of explaining it through physiological researches in the case of men and animals.

Rays of different wave lengths penetrate to different depths in the organism, the shorter the wave lengths the less being the depth to which the rays can penetrate the tissues. For example, if we allow the light from a quartz lamp to fall upon the cornea of the eye, we observe no alteration during the illumination; the reaction remains latent several hours before appearing. The outermost layer is destroyed whether the illumination lasts for an hour or for only five minutes. The rays which produce this effect remain absorbed in the outermost layers. The epidermis of leaves is coarser than the epithelium of the human cornea and will, therefore, absorb rays of relatively longer wave lengths from short waved light. Even after long continued illumination these rays fail to penetrate to the chlorophyl grains of plants or at any rate do so in a very slight degree; hence they can have but little influence upon assimilation; on the other hand their effects must be visible in the epidermis. We are justified in regarding the difference between leaves exposed to the sunlight and those in the shade and other phenomena of heliotropism as due to these waves. These phenomena, however, did not suffice to fully explain to me the significance of the experiment described above. I made further studies in the world of nature for a long time in the hope of discovering phenomena which might be explained by this experiment. I consulted botanists, foresters, and farmers, but I found no satisfactory explanation anywhere, and for this reason I long left my records unpublished until last year a single circumstance convinced me that I had found the correct explanation.

Some nature lover had planted an edelweiss at the foot of a monument in the Isergebirge. By reason of the transplantation from the Hochgebirge (higher mountain regions) to the Mittelbirge (middle mountain regions) this plant had assumed a form which resembled in all respects that of the plant which I had grown under the Euphos glass. The sunlight that travels from the upper regions to the mid-regions of the mountain suffers much loss of the ultra-violet rays during its passage. Thus the edelweiss was influenced in the same way as my plant, *i.e.*, the ultra-violet rays which reached it were reduced. I had produced in begonias, mignonette, peas and beans similar alterations of form to that exhibited by the edelweiss and in all cases it was similar alterations in conditions of life that occasioned these.

In order to understand these relations correctly we must know how rays of light and above all the ultra-violet rays are distributed in the atmosphere. We have no correct conception of the content of ultra-violet rays in daylight. If we break up daylight into its elements with a prism we perceive that the visibility of the light ceases at λ 400 $\mu\mu$. Beyond these limits rays exist which are distinguished by their chemical effects. When we photograph the spectrum we perceive that it extends considerably further than we can see, but even then we do not obtain a correct image since glass has considerable absorbent power, depending upon its composition and thickness, in the ultra-violet region. If we make use of a spectrograph with a quartz lens, the spectra obtained appear much longer. Under favorable circumstances the spectrum of sunlight extends as far λ 291 $\mu\mu$. The spectrum has been determined to have such an extent by means of lofty ascents in balloons. But even at ordinary levels when the conditions of the atmosphere are especially favorable, rays having waves of this length have been perceived. However, the intensity of these rays differs very greatly at different altitudes and in different seasons of the year. When the direct light of the sun penetrates the atmosphere it suffers considerable loss through refraction, reflection and bending and the shorter the wave lengths the greater the amount of such loss. Thus the diffusion in the smallest particle increases in inverse proportion to the fourth power of the wave length. If we assume that the light of λ 800 $\mu\mu = 1$, then the violet light λ 400 $\mu\mu$ will be 16 times as much diffused and the ultra-violet of λ 320 $\mu\mu$, considerable quantities of which rays are contained in daylight, even in the lowlands, will be about forty times as much diffused. The blue color of the sky is due to the increased diffusion of the short waves of light, since these rays become turned aside or split off from direct sunlight during their passage through the atmosphere. Another phenomenon due to this is the greater blackness of the shadows in the upper regions of mountains than in the lowlands. However, by reason of this peculiar distribution of sunlight in the atmosphere a large portion of the rays is lost before the light reaches the lowlands, especially the rays of short wave lengths. However, that even at low altitudes daylight contains a goodly portion of ultra-violet rays is shown by the spectra obtained by me in Dresden at the beginning of the spring with a quartz spectrograph. Half of the spectra obtained were taken upon an ortho-chromatic plate and were produced by rays which are not perceptible to the human eye. In the summer the intensity of the ultra-violet rays increases in a much higher degree than that of the visible rays and the spectrum therefore appears to be longer. In my pictures the end of the spectrum had such a feeble intensity that it was not capable of making an impression in the chosen time of exposure.

We are not yet able, unfortunately, to measure the amount of loss which daylight suffers in its passage through our atmosphere. Our apparatus is too imperfect. As a matter of fact the best apparatus which we possess for this purpose is our own skin. When we travel from the lowlands to near the top of a mountain this apparatus reacts promptly and vigorously to the increasing stimulus of the invisible rays, only a few hours being required to produce an acute reaction. "Glacier burns" and "snow blindness" are instances of this. When we expose our invalids to sunlight at a height of 1000 m. above sea level we know that the light still contains actively healing rays, though no longer capable of producing such violent inflammations as those mentioned above, and when we seek health at resorts in the medium high areas of our mountains that the sunlight there is a far more powerful source of energy than at low levels. As we travel from the extreme limit of plant life towards sea level the intensity of the visible rays steadily diminishes, and this decrease of intensity is even more marked in the ultra-violet rays.

EFFECT ON PLANTS OF VARYING INTENSITY OF LIGHT.

My experiments have proved that the form of a plant is altered when it is protected from the action of light rays of short wave length. A similar alteration was exhibited by the edelweiss plant which was taken from the Hochgebirge and transplanted in the Isergebirge. I learn from Prof. Neger in the Tharandt that shrubs reared in the Erzgebirge Botanical Gardens and transplanted in the valley in the same sort of earth exhibited longer sprouts. I do not hesitate to generalize these phenomena.

In the higher mountain regions we have a low form of vegetation of particularly vigorous growth. This form of growth is conditioned by the large quantities of rays of short wave length which act upon the plants in such regions. As we descend towards sea-level this stimulus diminishes, and plants increase in the length of their growth in direct proportion to this diminution. It cannot be denied that other influences, such as temperature, humidity, and air currents are likewise operative, but in my opinion light is so powerful a factor as far to surpass all others in importance.

The effects of ultra-violet light on plants have been extensively studied but the amount of ultra-violet rays con-

tained in daylight is still unknown. The spectrum of sunlight extends in the most favorable circumstances up to λ 291 μμ. On Mt. Rosa, in balloon ascents extending to 8000 m., the spectrum of sunlight has been found to have almost the same extent.

At the level of the sea, also, as well as in Potsdam, Cairo, Assuan, South Africa, rays have been found to extend likewise to λ 291 μμ, given favorable conditions of the atmosphere. The spectrum of the light from the quartz lamp and from the open arc light extend much further. It is possble to perceive clearly rays in these spectra extending as far as λ 200 μμ. That the spectrum of sunlight appears shorter than spectra from terrestrial sources of light may be due to the fact that the glowing ball of the sun is surrounded by a sphere of vapor which cannot be penetrated by rays of less than λ 291 μμ.

But even if the sunlight spectrum does not differ essentially at different heights, still the intensity of the light towards the short-wave end of the spectrum diminishes very perceptibly as we go towards sea-level.

In botanical studies of the effect of ultra-violet rays on plants the quartz lamp and the open arc light have generally been used, and the fact has been overlooked that a large portion of the rays of light from these sources is not contained in daylight. Thus J. Schulze informs us of the effect of light rays of λ 280 μμ upon plant cells without knowing that such rays are not found in daylight! In the Reports of the German Botanical Society for 1917 Ursprung and Blum published the results of their researches upon the injurious effects of ultra-violet rays. Only in the first part of their experiment did they interpolate a thin sheet of glass between the plant and the quartz lamp, and in this case alone did they have light somewhat resembling daylight in the extent of the spectrum. In the following experiments they omitted the glass. Consequently rays took effect in these experiments which are entirely unconcerned in the biological processes of plants in a state of nature. The ultra-violet rays found in daylight—so far as those degrees of intensity which affect biological processes are concerned—range from λ 400 μμ to about λ 295 μμ. Within those limits their intensity steadily decreases as the distance of their passage through the atmosphere increases, but unequally, and to a greater degree at the outer, than at the inner end. This decrease of intensity must find corresponding expression in vegetation. I believe that my experiment reveals the significance of this.

The ultra-violet rays also vary much more in the course of the year than do the visible rays. This variation must likewise be expressed in vegetation and this fact must be noted. Such biological processes occurring in nature can not be explained by researches in which light of less than λ 300 μμ was employed.

Tar Disposal in a Producer-Gas Plant*

A Method of Vaporising Tar That Has Proved Successful

IN the manufacture of producer gas there is formed a large amount of coal tar, which passes over with the hot gas in the form of a vapor and, when cooled, condenses into a tar fog consisting of finely divided particles that remain in suspension. This tar must be removed from the gas to avoid clogging of gas burners, sticking of engine valves and obstructing of gas-pipe lines. Along this line the Ford Motor Company is doing the unusual in that the tar is returned to the producer, discharged over the fire and successfully vaporized. The accompanying diagram of piping and much of the descriptive matter of this article apply particularly to the gas-producer installation of the plant at Ford City, Ontario, but are also more or less typical of the Highland Park and Dearborn plants.

Referring to the diagram, the path of the gas is from the producer through the downcomer and primary condenser to the low-pressure gas header. The gas from the several producers comes together at this point. The several gas exhausters receive their supply from this header and discharge through spun-glass tar extractors in parallel, thence through secondary or cooling condensers to the gas-distribution main or header. Considerable tar is removed from the gas by water sprays in the primary condensers and practically all the remaining tar is removed by the spun-glass tar extractors. A trace is removed by aftercooling water sprays in the secondary condensers.

At present the cooling water from the primary and secondary condensers is mixed and sent to the tar-settling tank where most of the tar settles to the bottom. The water from the secondary condensers in a short time will be diverted directly to the sewer, thereby increasing the efficiency of tar separation from the primary water. The low-pressure gas header acts as a tar receiver. The tar flows by gravity, assisted by the head of water in the settling tank and the gas-exhauster suction, from the tar-settling tank to the low-pressure gas header. The tar from the spun-glass extractors likewise flows back by gravity to this same gas header, assisted by the difference in gas pressure on the two sides of the exhausters.

*From *Power*.

Previous to 1916 the tar was a waste product of the gas-producer plant and was hard to dispose of on account of its pitchy nature and the impurities it contained. It was got rid of by being sprayed into the boiler furnace. The small saving in fuel in no way repaid for the nuisance of the frequent plugging up of the tar lines, clouds of black smoke from the stacks and the mess in the plant.

It seemed desirable to dispose of this tar by gasifying it in the producer. All efforts along this line previous to August, 1916, had been so uniformly unsuccessful that it was generally admitted at that time that the idea was not practicable. However, on the suggestion of H. F. Smith, who had previously done considerable work on the problem, another attempt was made at the Highland Park plant, which established the fact that the tar could be gasified and would increase the heat value of the gas. Profiting by this experimental work, when the Ford City plant was put into operation the producers were piped up to dispose of all tar. The development of details has been rapid. The several plants differ materially in respect to details of construction and operation, yet the essential features are the same and each accomplishes the same general results.

Temperatures are the most important factors in the handling of the tar. Good practice requires that the gas leave the producer at a temperature of approximately 1,000 deg. F. In the primary condenser the gas should be cooled down to about 125 deg., this being about the lowest temperature at which the tar remains liquid. If cooled too much, the tar particles will stick and build up on the spun-glass extractors. The temperature of the gas leaving the secondary condenser should be as low as the water supply available will permit in order to eliminate the last trace of tar and moisture.

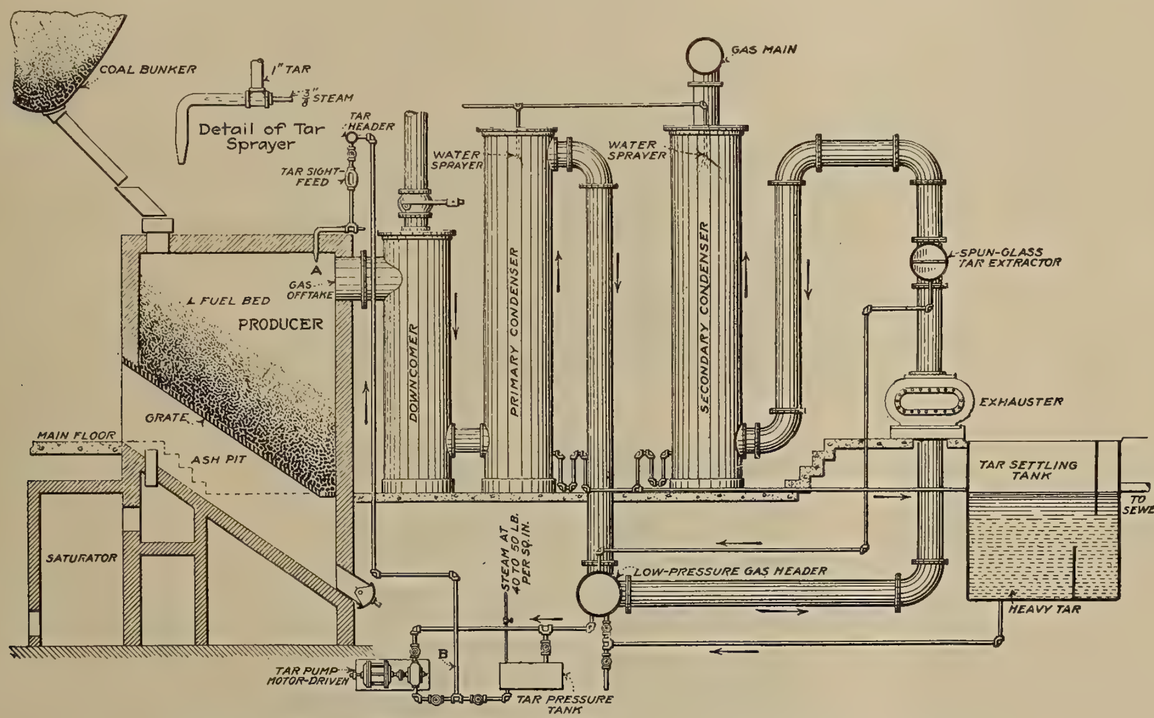
The tar that is collected in the low-pressure gas header in the basement may be pumped to the tar sprays in each section of the producer by a small rotary pump. The speed is regulated so as to return the tar at a slightly higher rate than it is received from the tar extractors and tar-settling tank. The pump may then be shut down, if desired, at times of light load.

As an auxiliary to the pump a small pressure tank is installed below the low-pressure gas heater. The tar flows by gravity into this tank, which has an overflow so that the small amount of water that may accumulate can be drawn off. When the tank is full of tar, the connections are closed off and steam is admitted at a pressure of from 40 to 50 pounds per square inch. The tar is discharged through a pipe from the bottom of the pressure tank and delivered to the producer sprayer *A* through the same pipe line *B* into which the tar pump discharges.

The advantage of the pressure tank method of handling tar is that it has no moving parts and the pipe line and all connections are blown clean of the tar by the steam after the tank has been emptied. On the other hand, the tar pump has the advantage of giving a more constant feed of tar to the sprays.

In the Ford City plant a 96-gallon pressure tank is used in preference to the tar pump. The objection to an intermittent supply of tar to the fire has recently been overcome by first delivering the tar to an overhead storage heater running the full length of the battery of producers. The tar sprays are keep the fuel bed in good shape and free from holes when spraying tar. The tar should be evaporated over the full area of the fuel bed and not burned as would be the case were there a hole in the fire. Five sprays are employed to insure even distribution over the fire. With a smaller number of sprays of tar the fuel bed under each spray became saturated with tar.

In the past considerable trouble has been experienced from solidifying of the tar in the pipes when the pump was shut down. This may come about due to cooling or to "baking." If the tar is allowed to cool in a pipe line, it is difficult to get it moving again. Provision is therefore made in every case for blowing tar from the pipe lines by the use of a ¼- or ⅜-inch low-pressure steam line run either inside the tar pipe or, preferably, on the outside and inclosed in the same pipe covering. The pressure on these steam lines should be five pounds or less. Tar should not be allowed to remain quiescent for any considerable length of time in a pipe even though heated, since the lighter oils will distill off and the residue harden or bake in the pipe, making a condition as bad as or worse than when it solidifies owing to cooling. The new sight-



DIAGRAMMATIC VIEW OF THE ARRANGEMENT OF THE TAR-PIPING SYSTEM

supplied continuously from this header. With continuous operation and constant maintenance of temperature throughout, it has been found possible to keep the tar so fluid that it is being fed like oil through sight feeds to each section of each producer.

The sprayer by means of which the tar is atomized and distributed over the fuel bed is made by placing a ⅜-inch steam pipe inside a 1-inch tar pipe. The ends of the steam pipe and tar pipe are reduced in area so as to increase the velocities of the steam and tar to aid in the atomizing. The ends of the sprayer are approximately flush with the bottom face of the top lining of the producer.

Vaporizing the tar increases the heat value of the gas about 10 to 15 B.t.u. per cubic foot. The difference shows up in the analysis of the gas in an increase of from 1 to 2 per cent of methane, accompanied by a slight reduction in the percentage of hydrogen.

The chief trouble encountered when first returning the tar to the producer fire was the formation of soot when the tar was sprayed upon a fire that had holes in it. This soot, if allowed to accumulate, would plug up the spun-glass screens in the tar extractors in a very few minutes. It is necessary to feed tar system requires that the temperature of the tar be maintained at about 160 deg. F., and for this purpose a low-pressure steam pipe is run inside the tar header over the producers.

TUNGSTEN IN BURMA.

TUNGSTEN and tin occur in Burma and mining on a small scale, particularly for tin, is an ancient industry. Military need for tungsten has caused general interest in the world's resources of the metal and has caused the Geological Survey of India to publish a summary, prepared by Messrs. Brown and Heron, on the deposits in Burma.

Active prospecting has been carried on in recent years and a considerable amount of tungsten has been produced. Usually wolfram and casiterite occur together, but sometimes they occur separately. The ores are found in lodes and are always associated with an intrusive granite that forms the core of the great mountain system which stretches into Western Siam and the Malay States. The authors believe that conditions are favorable for the discovery of further deposits in the vast areas of Burma which are as yet imperfectly known.

A Wireless Storm Detector for the Central Station

Anticipating Thunderstorms and Atmospheric Darkness at the Power Plant

By Herbert T. Wade

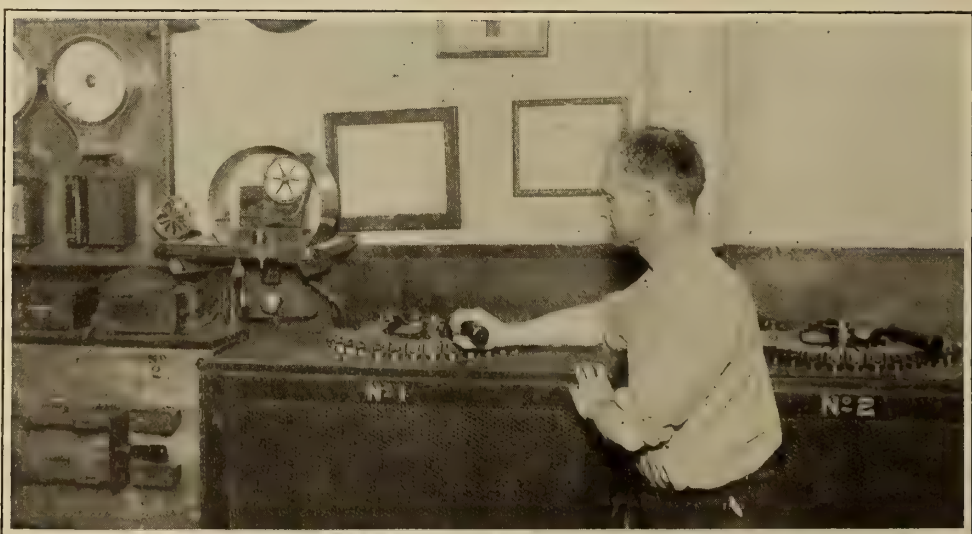
IT is not generally realized how intimate is the connection between meteorology and many fields of applied science and industry, but a striking instance is found in the public service company that supplies light and heat. In connection with schemes of daylight saving, the shortening of the time during which artificial illumination is required and the consequent saving of fuel has figured prominently, and the superintendent of the electric lighting company is a close observer of the changing time of sunrise, as his load will vary accordingly. This, however, can be anticipated in advance and the experience of previous years availed of, but when a sudden thunderstorm or other atmospheric disturbance comes, where the sky is darkened in the middle of the day without warning, the matter is an emergency which requires hurried and vigorous measures in the power house. When a city is covered with virtual darkness in the middle of the day, it means that resort must be had to artificial illumination, and immediately electric lights in great numbers are switched on, thus producing a sudden and abnormal load on the system, say at two o'clock in the afternoon, when under ordinary circumstances it would be at least six or seven o'clock, or even later, before the peak would be reached. A storm producing such sudden darkness may come up quickly, and apparently without warning, so that it would seem impossible to provide at short notice sufficient current or steam for the engines or turbines driving the generators. In the larger cities the usual practice is to have a central station of considerable capacity and to distribute alternating current to various substations conveniently located, at which it is transformed to whatever voltage is employed for lighting or power. At these substations the transformation of current from the central station is effected by rotary converters. Of course when an increased load comes upon the substation, due to the turning on of a number of lamps, it is a simple matter to start in operation additional rotary converters and thus secure increased current. This, however, simply increases the load on the central station, where adequate steam must be provided in the boilers to operate the turbo-generators.

ROTARY CONVERTERS AT SUBSTATION

These convert alternating currents to direct for distribution

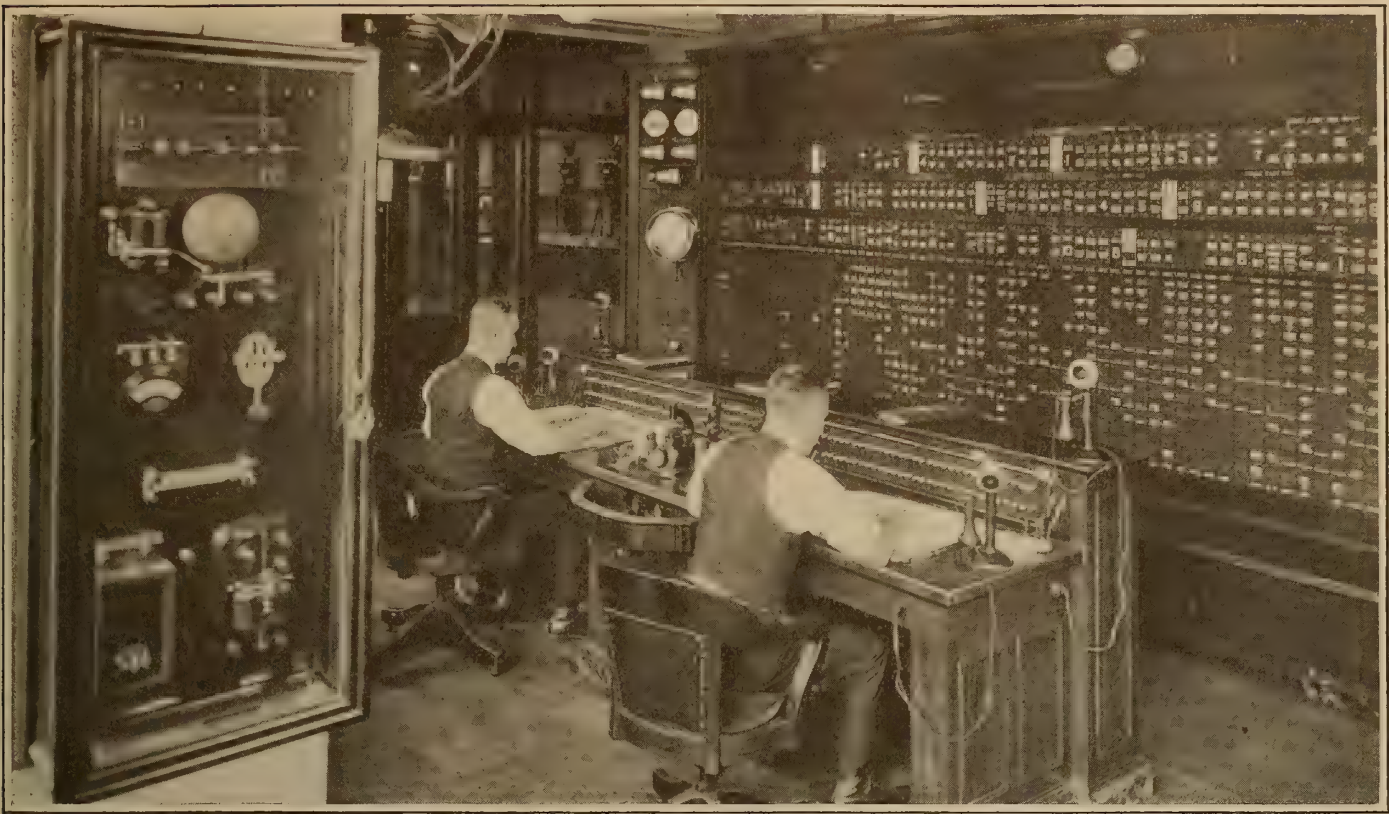
Accordingly the electric light company seeks to know as far in advance as possible the coming of a thunderstorm, and at the Waterside Station of the N. Y. Edison Company there is maintained a wireless signal at the central control office, where a threatened change in atmospheric conditions presaging a storm is announced to the system operator, some time before the arrival of the storm, by the ringing of a bell.

It is apparent that an electric light central station is required to function so as to provide adequate current for lighting, whatever the condition of weather or sudden calls that may be made upon the system. Naturally it is unable to maintain a reserve in any central reservoir, as in the case of gas or water, but the current must be generated and distributed immediately as required. The management of a central station, therefore, is forced to study the ordinary conditions of its daily operation and load very carefully, and accurate and detailed records are made and studied so as to know at what times of day the natural increase or decline in consumption will take place under normal circumstances. In addition a central station is forced to provide for sudden and unusual drafts on the current, some of which may be anticipated, and some of which may come without warning. For example, in the case of a general illumination, it is quite possible to arrange in advance, but where a sudden thunderstorm or darkening of the atmosphere occurs, and everybody immediately switches on their electric light, it is not always possible to foresee this sudden demand in time to provide the required capacity. It is true that each substation of a system may maintain a storage battery installation that will carry a certain portion of the load for a more or less brief interval of time and be available while other parts of the system are out of commission until repairs are rapidly made, or until sufficient generating capacity is added. For example, in New York the direct current substations in Manhat-



STARTING ROTARY CONVERTER

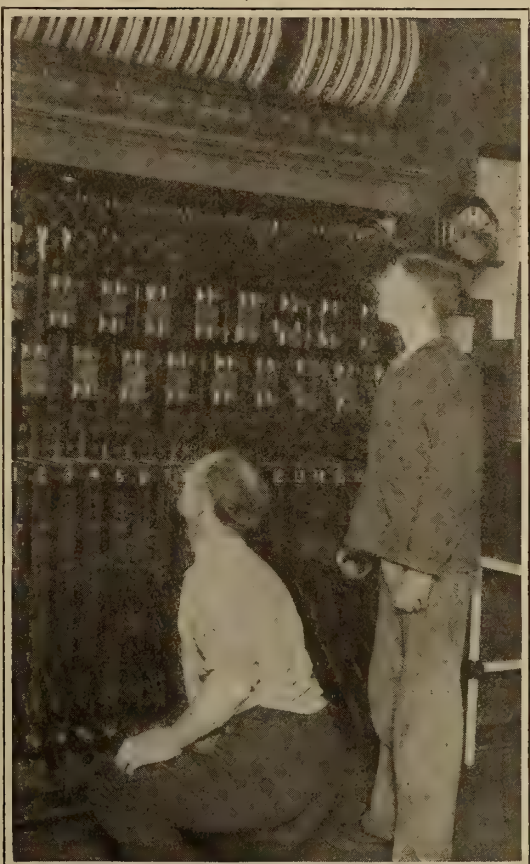
Starting box used to start and turn over a rotary converter



SYSTEM OPERATOR'S DESK AT WATERSIDE STATION OF NEW YORK EDISON COMPANY
Storm detector is in case at left and pilot operating board in background

tan of the New York Edison Company have a battery capacity of 50,000 kilowatts for one hour, and every substation has its battery. In the main, however, dependence must be placed upon the boilers and generators at the central station, as the approved system of electric lightning now calls for a high capacity central station with large steam turbine-driven units which generate alternating current and distribute it to various substations located throughout the city, where it is transformed by rotary converters to direct current and distributed within the immediate territory served by the substation. The New York Edison Company represents a typical installation, yet at the same time it is in many respects so far in advance of the best average practice as to be unique rather than characteristic of a large capacity station.

At its Waterside Station, located on the East River, convenient for unloading coal, a number of steam turbine-driven generators are maintained which produce alternating current, 25 cycles at 6,600 volts, which is then distributed throughout Manhattan Island to various substations of the Company and to such independent substations as the high pressure fire pumping plants of New York City, contractors engaged in subway construction, street railway companies, etc. The efficiency of the plant demands that the boilers should be run at their most economical rating, and the amount of steam produced is considered with regard to the daily and ordinary fluctuation of load. Where the boilers are run at an economical rating, 30 per cent above this amount readily can be taken care of, and in addition a certain number of boilers are carried banked, which can be brought up to steam pressure with 150 per cent load in about five minutes. To bring up a fresh boiler that has been inactive, two or three hours are required. It will be seen, therefore, that the boilers are the main consideration in case of sudden increase in load, as the turbine-driven generators can be put on in a couple of minutes, provided there is steam enough to take care of them.

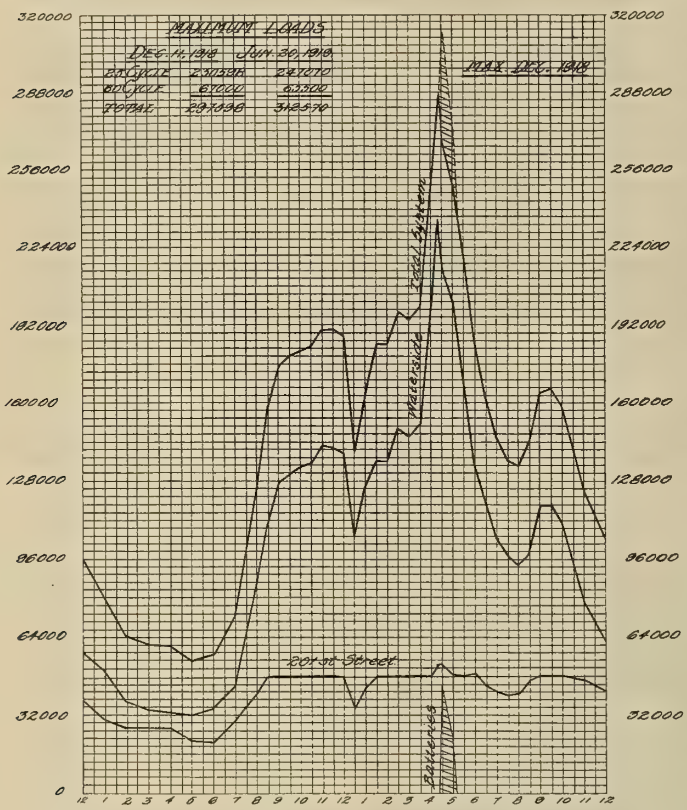


DIRECT CURRENT SWITCHBOARD AT SUBSTATION

In a system like that of the New York Edison Company, the various substations are connected by feeder cables with the main generating station at Waterside, and these substations add their various rotary converters, as increased current is demanded in their immediate district. These drafts must be met at the main central station at Waterside, and in case of a sudden storm darkening the entire city, the amount of extra current required may run up from 50 per cent to 75 per cent. As will be seen from the diagram on page 20 on June 20, 1919, between 3:30 and 4:20 in the afternoon, current consumption increased 120,000 kilowatts, where-

as on a normal day it would have remained stationary or possibly declined. Supplied from the one central station at Waterside there are 27 substations devoted to direct current illumination in Manhattan, and a number of substations belonging to large consumers such as the city, traction companies or contractors. In addition, in the Bronx and outlying districts alternating current at 60 cycles is supplied also from Waterside, but transformed to 110 volts.

It will be apparent, therefore, that those in control of the Waterside central station, even with its large capacity, require the earliest possible warning of an approaching storm or atmospheric conditions that will lead to darkening the atmosphere and the demand for more current. It was with this in mind that the electric storm detector was devised with its antennae or aerial wires mounted on the roof of the Waterside Station and its signal and indicating mechanism in the office



LOAD DIAGRAM ON JUNE 20. 1918—SUDDEN RISE DUE TO THUNDERSTORM

of the system operator, who is responsible for the entire operation of the generating and distribution system of the plant.

The system operator sits in an office where he has under his observation an operating pilot board with interconnecting control signals and indicators that show the entire functioning of the various stations and elements of the system, and he is responsible for the providing of additional and adequate capacity, so that both the ordinary and sudden loads may be taken care of. He and his assistant sit at a desk, as shown in the illustration, and in front of them is a pilot board, where is indicated each generator in the central station and its connection with the bus bars and the distribution of the feeder cables to the various substations. Each of these feeder cables has an approximate capacity of 3,000 kilowatts, and in some cases 4,000, and on the board each of these leading to the substations is indicated. On the lower part of the board the indications represent the various substations and their feeders, and the lights show which of these are in use. This board, which is unique in being the only one of its kind, is absolutely automatic, and shows the condition of the generating units and capacity and the distribution to the substations for the entire system. A red light indicates just which feeders are in use, and any interruption of service is shown by a green light. These bullseye telephone lamps are part of a circuit that extends to the oil switches of the main feeder circuits and indicate automatically and instantaneously whether these circuits are open or closed. The various substations are connected by tie feeders, so that a complete interdependence of the various elements of the system is assured and failures of certain lines can be taken care of.

In brief, the system operator, who is connected by direct telephone circuits with each of the substations and pneumatic tubes and signals with the boilers and generator rooms, is able absolutely to control the operation of the system. Indeed, in case of an emergency he has at his command a regular fire alarm transmission system, extending to each substation over which he may send out instantaneously and simultaneously various code signals. In the boiler room there is a signal like the carriage calling device at a theater, and when a new boiler is ordered into service, the appropriate punched card is inserted in the transmitting machine and the signal is made. The responsibility of this office can be appreciated, as the entire economy of the station and system are here controlled involving the provision of an adequate supply of current to satisfy the various consumers. If an over-capacity of boilers is maintained, it is done at the expense of fuel, while on the other hand, if the system is caught at some time of sudden darkness with inadequate capacity, the trouble is no less serious. It will be apparent, therefore, what part meteorological conditions play in the ordinary routine and maintenance of the station and why the system operator needs the earliest possible warning to increase his output or prepare for sudden demands.

In the summertime a heavy thunderstorm may bring practical darkness to the city and produce a condition so different from the ordinary routine seriously to threaten the efficiency of the service. In the winter such matters do not figure so largely, as the ordinary load is so much greater that the sudden increase due to the darkening of the atmosphere does not tax the system so seriously. In summer, however, storms are likely to come up suddenly and the atmosphere considerably darkened, so that electric light is switched on generally, and the load on the lighting system may increase 50 per cent or more. The most striking instance of this sudden increase of load is shown in the accompanying curve for June 20, 1919, which shows actual output in excess of the previous maximum capacity of the entire system namely, that of December 11, 1918. On June 20th the maximum load at 4:20 P. M. amounted to 312,570 kilowatts, while on December 11, 1918, the previous maximum, it was 297,598 kilowatts.

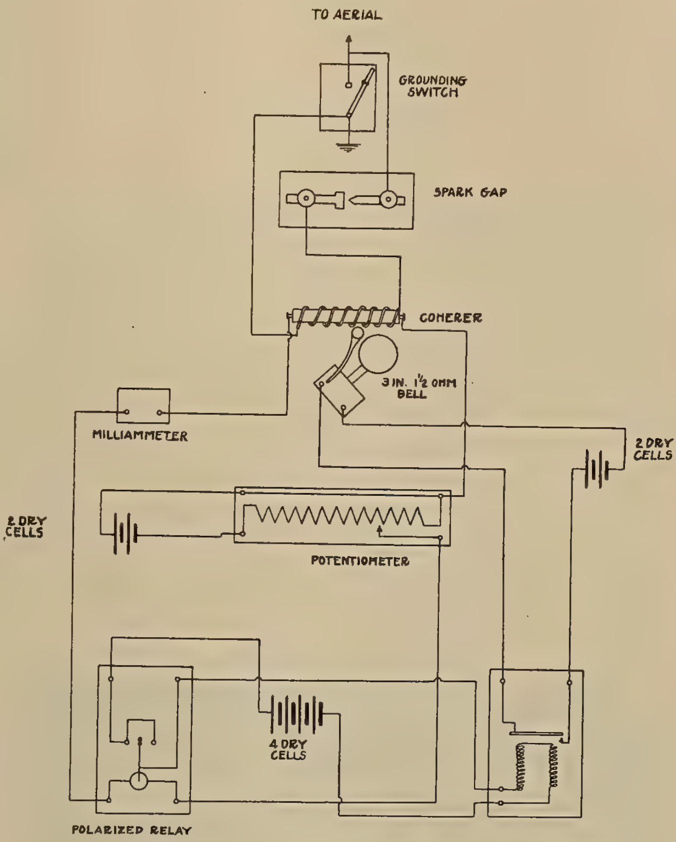
Such conditions as these naturally demand every measure to give warnings of storms as far as possible in advance, and it has been found that weather bureau reports are not always accurate for this purpose, nor do they indicate storms which actually strike the territory as distinct from those which pass around it. Accordingly a special form of storm detector was devised some years ago and has been in successful use at Waterside Station. Inasmuch as summer storms are accompanied by electrical disturbances of the ether, which are indicated by means of a special form of wave detector, it was decided to install such an instrument at the Waterside Station, as these electrical disturbances cover a field further distant than the clouds themselves are visible. Accordingly a system of antennae is used to intercept such distant radiations and to indicate by suitable form of detector and signal not only the presence but the relative proximity of the storm. As stated, this is confined largely to summer storms, as the winter storms are usually snowstorms and of a weak electrical nature, while at the same time the load carried by the station in winter is more uniform, and no storm ever comes up to the peak of the load ordinarily carried between 5 and 5:30 in the afternoon. In the antennae, mounted on the roof of the station, the presence of electrical disturbances in the atmosphere gives rise to oscillating currents which travel

through the aerial to the ground through the spark gap coherer and condenser. The general arrangement of the apparatus is indicated in the accompanying diagram, and is shown on the left of the photograph of the system operator's office. At the top of the diagram will be seen the short circuit switch which grounds the apparatus when it is closed after the bell rings continuously. Inasmuch as by that time the storm has already arrived, it is not necessary to use the apparatus, and it is thus protected from the heavy surges. Next the aerial circuit is connected through a spark gap supplied with spherical terminals about 1/64 of an inch apart and a coherer of the type formerly used as a receiving device in wireless telegraphy. The function of the spark gap is to prevent those electrical surges induced in the antennae by the radiations emanating from wireless telegraph stations, which are very weak as compared to the electrical disturbances in the atmosphere, from flowing through the remainder of the apparatus and thus causing a false alarm. The coherer is also in circuit with a milliameter, a polarized relay, a standard relay, and a single stroke bell whose clapper not only strikes the bell itself but also the glass tube of the coherer, causing the particles in the latter to decohere after each impulse. The action of the apparatus is sufficiently apparent from the diagram, and it involves no applances that are special or unfamiliar. It is completely automatic in its operation. At a time varying from 2 to 7 hours, depending upon whether the path of the storm is direct or roundabout, the bell may begin to ring at intervals of from five to fifteen minutes, giving a warning of some distant atmospheric disturbance, indicating a storm possibly one hundred miles away. This is regarded merely as a preliminary warning, for as the storm approaches, the bell will ring more frequently. When about two hours away, the bell will ring about once every half minute or minute; and when this occurs, the reserve boilers are ordered into service and the auxiliaries of extra generating units are started and the generating units themselves may be run at low speed. This is entirely preliminary and by way of preparation as the storm may be approaching yet pass by at a greater or less distance. The bell rings continuously about one-half or one hour before the storm reaches the city, and even at this time the sky may be unclouded to the eye, even to an experienced storm observer. However, everything now is in readiness to meet the demand, and with the bell ringing continuously the short circuit or ground switch is then opened so as to protect the apparatus. The storm warning involves entirely a measure of preparedness and attention to the immediate boiler and generating capacity available and the ordering of banked boilers into full service and other boilers as may be required, or, in case of an extreme emergency, the batteries.

As soon as the storm strikes the city, the switching on of electric lights means extra drafts on the current supplied from the substations. Those in charge of these plants notice that the amount of energy consumed is increasing, and they immediately add extra rotary converters to take on the load. These rotary converters take the alternating current at 6,600 volts, 25 cycles, and transform it into direct current at 120 volts, except in some cases in the upper parts of the city and suburbs where customers are supplied with alternating current at 110 volts.

The work at the substation, which is shown in several of the accompanying photographs, is of course not as involved as at the main central station where the energy is generated. Nevertheless rotary converters must be held in readiness for instant service. When it is found that more capacity is required, extra rotary converting units are started up, the operation being as shown in the accompanying figures. The amount of current is increased as required, and the system operator at the Waterside Station notes the load carried by the feeders running from the generating station to the substation and keeps up the capacity. Here those in charge note the consumption of the direct current supplied by their rotary converters, and the photograph shows the direct current switchboard where the sudden overdrafts are first apparent. Here, as stated, more rotary converters are added as needed, this of course making a corresponding load on the feeders and on the main generating system. The feeders carrying the direct current from the substation to the consumers are shown in the accompanying illustration:

Where large currents at high voltage are used, an oil switch is required. In contrast with the heavy oil switches, small hand switches shown on the lighting panel of a substation are of interest.



WIRING DIAGRAM OF STORM DETECTOR AT WATERSIDE STATION

The substation is at all times in complete communication with the system operator by telephone and indicator, and while its responsiblities are far less than the main generating station, yet its needs and the needs of the consumers must be taken care of immediately.

It should be borne in mind, however, that a system so large as that of tie New York Edison Company can be and is under a single control, and the ingenious device described above is but one element in this vast distribution of light and power, although it helps to take care of the very important item of sudden overloads due to atmospheric conditions.

THE ELECTRICAL INDUSTRY IN BELGIUM

The electrical industry in Belgium is gradually resuming its activity. The main difficulty, however, is that it is practically dependent on foreign countries for the supply of the material required. In the large towns, Brussels in particular, a start has been made to lay the supply cables that were held up during the war. The networks that were removed by the Germans are also being replaced. A significant indication of the activity which is anticipated in the industry is the increasing formation of new companies and groups dealing with contract work and the purchase and sale of material. Many existing firms are considerably increasing their capital.—From *The Technical Review*.

Submersible Sea Salvage Pumps*

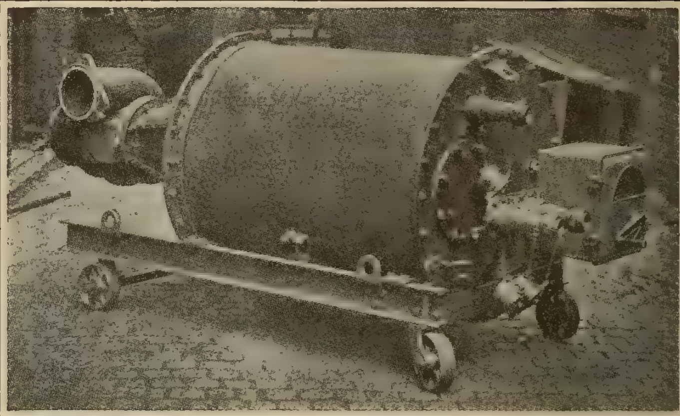
A Portable Apparatus for Pumping out Flooded Compartments

DURING the war, as we know, an enormous amount of time and attention was devoted by inventors, scientists, naval architects, and shipbuilders, to the possibility of keeping a ship afloat after she had been badly holed by mine or torpedo. It is quite obvious that if a compartment is so severely damaged as to allow of the proverbial coach and horses being driven through it, no pumping apparatus that human ingenuity can devise will keep the water out. It is, however, quite within the range of possibility that the compartments adjacent to those damaged may be kept free from water, even if the bulk-heads, through strain, are leaking freely, provided apparatus is ready for instant use in such an emergency. That apparatus must be both reliable and powerful and easy to handle. It is now a well-known fact that the large steamship companies suffered very heavily from enemy action, and it is known that on several occasions, when a ship was mined or torpedoed near shore, she could have been successfully beached and subsequently salved had it been possible to keep the water out of only slightly damaged compartments for a few hours.

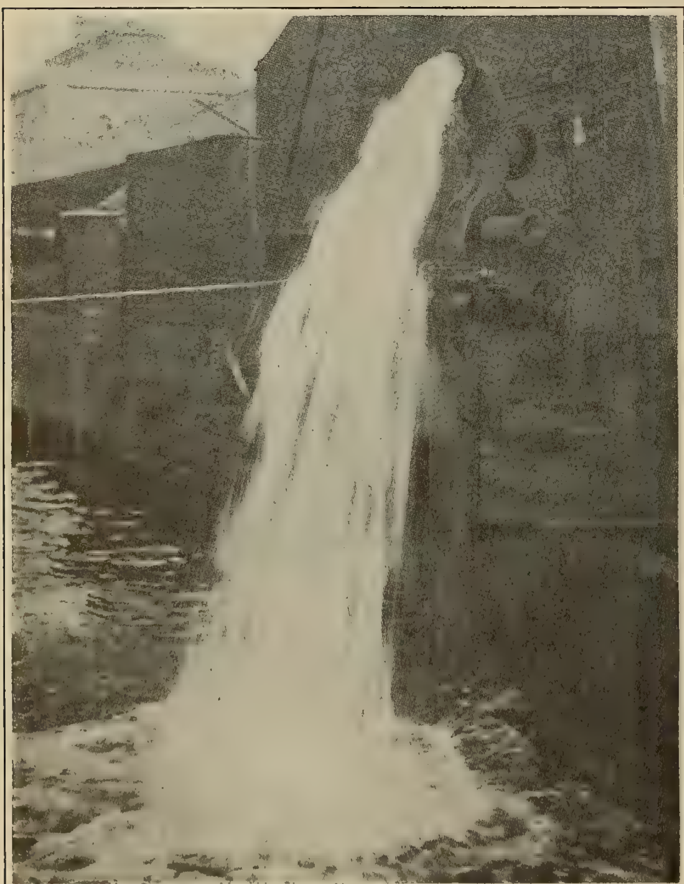
The portable electric pumping apparatus here illustrated has been specially designed and constructed to meet such requirements as those brought about by the conditions we have just indicated.

At the present time, there is probably not a ship at sea; at any rate, not a ship of any size, which is not equipped with an electric power installation for lighting purposes, and some have a special power plant on the upper deck, entirely separate from the ship's ordinary lighting set in the engine room, and intended to be used in an emergency. This special power plant is, we believe, rendered compulsory by the Board of Trade to meet the regulations laid down by the International Convention for the Safety of Life at Sea, drawn up prior to the war, and which, it is hoped, although many times postponed on account of the war, will soon become effective on all the high seas of the world. Should it so happen, therefore, that the vessel be damaged in the vicinity of the engine-room and the dynamos put out of action, the emergency plant would come instantly into operation, and provide current for lighting, for operating the ship's derricks, and for driving such a portable pumping apparatus as that which we are now describing.

*From the *Shipping World.*



ELECTRICALLY-DRIVEN SUBMERSIBLE SALVAGE PUMP



THE SUBMERSIBLE PUMP WORKING UNDER WATER DURING A 48 HOURS' DURATION TEST

The electric submersible pump consists of a centrifugal pump of the standard sea salvage type, coupled direct to an electric motor carried in an hermetically sealed steel cylinder. A special feature of the apparatus is an intercepting chamber arranged between the motor and pumps, forming subject matter for which a patent has been applied, and which is designed to prevent any posibility of water from the pump chambers finding access to the electric motor. That the success of this device is assured is demonstrated by the fact that a continuous working test of forty-eight hours' duration, with the pump completely submerged has failed to show the slightest leakage of water into the motor cylinder. Moreover, for well proved reasons a ship's power plant is almost without exception designed to a low voltage continuous current, and the submersible pump can be successfully operated direct from an ordinary ship's lighting set. This, it will be readily appreciated, is an extremely important feature.

The submersible pump illustrated, has an 8-inch diameter suction, and is capable of giving an output of 1,100 gallons per minute against a head of 35 feet. An overall efficiency of 75 per cent has been demonstrated by actual test, which is extremely high for this class of pump.

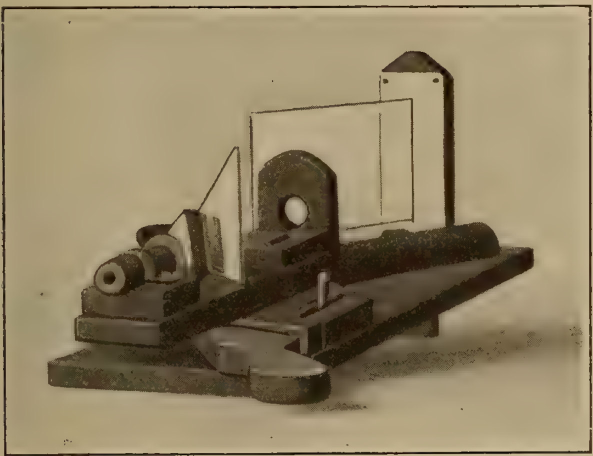
These pumps can be operated when slung vertically or when fixed in a horizontal position, either on or off the trolley with which each is supplied. Although they will run successfully when totally submerged, they will run equally well when fixed above the water level. It should be recognized that in most instances where access has to be obtained to a flooded compartment, it is, generally speaking, more convenient to use a length of flexible suction piping of such a diameter that it can be inserted through a small orifice—such as a porthole, for instance—than to lower the complete pump into the water; and it will, we think, be found in actual salvage practice that the necessity of submerging the pump would arise on comparatively rare occasions. There are, however, cases in which a rapid rise might flood the pump, and hence the necessity for constructing it in such a manner as to

allow of its continuous operation under the most adverse circumstances. The power cable connections are, of course, watertight, and arranged with a swivelling nut, much in the same manner as a standard screwed hose coupling. Each pump is supplied with a hand-operated air pump fixed to the carriage, for charging the pump suction when operated from about the water level.

REFRACTOMETER FOR POLISHED PLATE GLASS.

BY K. A. RICE, M. E.

A REFRACTOMETER which determines the index of refraction of polished plates of glass, accurate to the third decimal place may be made as follows. A simple telescope consisting of two lenses of three or four diopters focus each, and having a card with a narrow slit (.02" wide) at their common focus is mounted upon a slide which permits the telescope to be shifted at right angles to its line of collomation. The slit in the card must be vertical. The telescope is mounted on a base board between two cleats which run crosswise to the length of the board, and one of which is provided with a clamp for holding the telescope rigidly in any desired position. At the end of the board opposite to that occupied by the telescope is placed a second card with a vertical line drawn upon its inner face. Between this card and the telescope a cleat is secured to the base at an angle of 30° with the center line of the base, against which the plate to be measured is placed. A simple clamping device holds the glass in position snugly against this cleat. Means are provided for accurately measuring the position of the telescope with respect to a fixed point on the base, two steel rods being used in this case, one on the telescope slide and one on the slide guide, the distance between them being measured by means of ordinary micrometer calipers.



DETERMINING THE INDEX OF REFRACTION OF A PLATE OF GLASS

In operation, several measurements are made of the thickness of the glass by means of the micrometers, and the average of these noted. Ten readings are recommended. Then, sighting through the telescope, with no glass in the path, the telescope is shifted until the farther black line is located in the center of the slit (the line also being in focus), and clamped in this position. Then the distance between the outside edges of the steel rods is measured and noted. Now the plate is interposed, being clamped against the 30° cleat, and the telescope shifted until the line again appears in the center of the slit, clamped, and measurement between steel rods again taken. It is well to take ten readings for this value also, taking five with the glass in different positions with the end in one direction, and five in different positions with the glass turned end for end, in order that any defects in the glass, such as local imperfections or to a wedge shape between the two surfaces, be compensated. The average of these readings is found, and the zero reading (reading without the glass) is subtracted from this, giving the value "*d*". This number is divided by the thickness as found above, and with this last result, the index of refraction may be read directly from the curve.

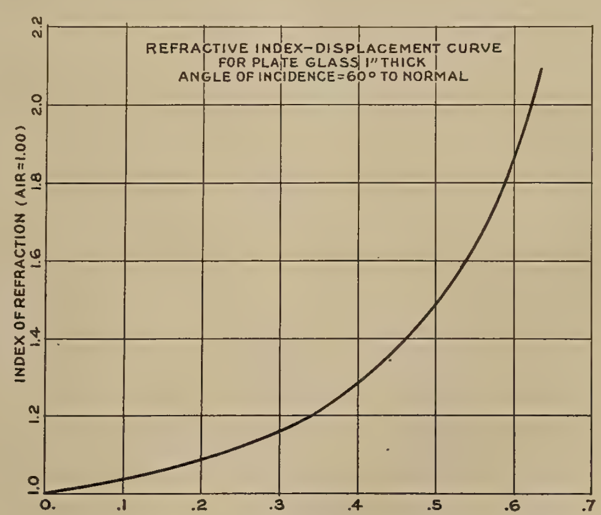
The theory upon which this apparatus is based, is that when a beam of light passes through a plate of glass with parallel surfaces, the beam is emitted in a line parallel to that of the original beam, but displaced from it by a distance which depends on the index of refraction, the thickness and the angle at which the glass is interposed. This latter must obviously be other than 90° or 180° to the normal. With this in mind, the following formula was developed for the index of refraction, in which Θ is the index, t is the thickness, and d is the displacement, the angle employed being 30°, or 60° to the normal:

$$\Theta = \frac{\sin 60^\circ \sqrt{t^2 - 2td \sin 60^\circ + d^2}}{t \sin 60^\circ - d}$$

From this equation it is evident that, the index of refraction and the angle of incidence being constants, the displacement of the refracted beam is directly proportional to the thickness of the glass. Therefore the curve was calculated for an angle of 30° to the glass, or 60° to the normal, with index values ranging from 1.0 to 2.0, and with the thickness 1 inch. When the curve is used, the value for d obtained from the instrument must be divided by the thickness of the glass, as explained above, in order to reduce it to an equivalent plate of that standard thickness. The computed points on which the curve is based are as follows:

Index	Displacement
1.0364	.08
1.0612	.16
1.1061	.24
1.1743	.32
1.2702	.40
1.4270	.48
1.6588	.56
2.1026	.64

It is evident that the last figure in the indices as above computed cannot be plotted on this curve, so it was eliminated by reducing the index values to three significant figures beyond the decimal point. A sample computation of refractive index is submitted as a guide.



Ten readings for thickness ran from .0826 to .0831, with .083 as the average. The glass readings varied from .392 to .394; the average was .393; and .347 was the zero reading. Then d=.393—.347=.046 inches. This value for a thickness of .083 reduces to .046÷.083 for a thickness of one inch, so that the corrected d=.554; then from the curve, 1.635 is the index of refraction corresponding to this value of d.

Automatic Regulation of Humidity in Factories

Conditioning Apparatus Developed at the U. S. Forest Products Laboratory at Madison, Wis.

IT has long been known that green lumber warps out of shape and that the grain curls excessively when planed or carved, so that for use in furniture and cabinet work lumber must be dry. From one to two-thirds of the weight of a tree, when it is cut down, may be due entirely to the water it contains. If the wood is left exposed to the atmosphere, the moisture is slowly given up, until equilibrium with the atmospheric conditions is reached. In some climates this occurs when the moisture is 27 per cent of the weight of air dried wood; in others not until the moisture content becomes 4 or 5 per cent. Air-drying is usually a slow process and is accompanied by serious checking and warping. The artificial drying of wood without injurious results can be accomplished only by a careful drying schedule. It is possible, however, to cut the material up and dry it in kilns to any desired content without the materials becoming checked or warped.

Wood contains water in two forms, either as free water, like honey in the comb, or as hygroscopic moisture, actually permeating the cell-wall tissue. No change in shape takes place while the free water is being removed, but as soon as hygroscopic moisture is removed, the wood shrinks. This shrinkage is different in degree for every species of wood, and even within a species it is different in each of the three directions in a tree—radial, from the heart toward the sap; tangential, along the circumference, or the annual ring; and longitudinal, from top to bottom in the tree. With any change in hygroscopic moisture, there is an immediate shrinking or swelling of the wood in each of these three directions, and by a different amount in each direction.

Changes in moisture content, then, are important because they cause wood to shrink or swell. If the moisture content of a piece of furniture changes after it is made up, the dimensions of the different pieces will be altered, and, since the alteration may not be the same for all parts of a piece, warping is likely to take place. If the moisture content of the material used in making a single piece of furniture is not uniform at manufacture, it will become uniform after manufacture, and, while some parts may shrink, others may swell, and severe warping and checking or even splitting may occur. This is particularly true in the manufacture of airplane propellers and fine cabinet work, where pieces have been made to fit exactly. In such articles severe stresses are set up with small moisture changes. In airplane propellers these stresses frequently cause joints to open, blades to warp, and the propeller itself to go out of balance.

The moisture content of wood has been found to depend upon the temperature and humidity of the atmosphere in which it is placed. By controlling the atmospheric conditions, it is possible to bring and hold the moisture content of wood to any desired value.

Along with other problems relating to the moisture changes of wood, the problems of the proper moisture content for specific war purposes became acute enough to require particular investigation. With the establishing of an airplane propeller plant at the U. S. Forest Products Laboratory at Madison, Wisconsin, the necessary rooms were provided in which the atmosphere could be controlled and its temperature and humidity held at any desired values, irrespective of outside atmospheric conditions.

Conditioning devices may be divided into three classes—non-controlled, semi-controlled, and absolutely controlled. The non-controlled type includes such methods as running water in troughs along the side of the room, or passing the air over wet wicks. Other examples that may be given are the sprinkling of water or wet sawdust on floors, or the spraying of water directly into the air. The semi-controlled type includes most of the commercial forms of humidifiers. These are capable of increasing the humidity up to the value for which they are set, at which point the apparatus stops operating. The controlling feature for these types is usually some cellulose material, such as wood or fiber. This type of apparatus is not capable of reducing the humidity. The absolutely controlled type is capable of reducing the humidity, as well as increasing it.

Relative humidity may be decreased in several ways. The air may be heated without addition of moisture; this is what ordinarily happens in factories during cold seasons. Cold air is drawn in from the outside, is heated, and circulated throughout the shops, giving relative humidities of 10 to 20 per cent; while in the warm seasons, the relative humidity would be as high inside the shop as outside, usually from 45 to 00 per cent. Low relative humidities could be secured in summer as well as in winter by heating, but the necessary temperature, probably 120° F. or more, would be excessive. Refrigeration could also be used to secure low relative humidities, but the apparatus would be somewhat expensive both in installation and in operation. The apparatus finally chosen for the Forest Products Laboratory Propeller (rooms) is automatic in its operation. It is capable of acting either as a humidifier when the humidity is below the value desired, or as a dehumidifier when the humidity is too high. The principles of operation are those of the water-spray dry kiln, which has been successfully used in commercial operations. The details of this humidity controlling apparatus were designed by H. D. Tiemann, M.E. M.F., patentee of the water spray dry kiln.

RELATIVE HUMIDITY.

In order that the theory and operation of the humidity and temperature controlling apparatus may be made clear, a short discussion on relative humidity is given.

The maximum amount of water vapor that space can retain at any given temperature is always the same. More moisture cannot be injected without condensation's taking place. Under such conditions, the space is said to be saturated. The presence of air does not interfere with the presence of the water vapor and the ordinary expression is that the atmosphere retains the water vapor. With an increase in temperature, the capacity to retain water vapor is increased; and with a decrease in temperature, the excess moisture is condensed out.

Relative humidity is the ratio, expressed in percentage of the amount of water vapor actually present in the atmosphere to the amount for saturation at the same temperature.

Since the capacity to retain water vapor increases with increase in temperature, it is possible to secure low relative humidities simply by heating the atmosphere without adding any moisture. The amount of water vapor required to saturate the atmosphere at 60° F. is only one-half that required to saturate it at 80° F. If the atmosphere be saturated at 60° F. and then heated to 80° F., without the addition of moisture, its relative humidity will become 50 per cent. If we saturate air at 41° F. and heat it to 80° F., we get only 25 per cent relative humidity. Evidently we can get any humidity we desire at 80° F. simply by choosing the temperature at which we saturate the atmosphere, and then heating it. This can be done for any room temperature; so that, in order to control the humidity, it is necessary only to control the temperature at which the atmosphere is saturated, otherwise called the dewpoint temperature, and the temperature to which the atmosphere is then heated. In Fig. 1 are shown the curves from which the dewpoint for any room condition can be determined. The curves beginning at the top of the sheet and dropping off toward the right indicate the actual water-vapor content of the atmosphere under any condition, and

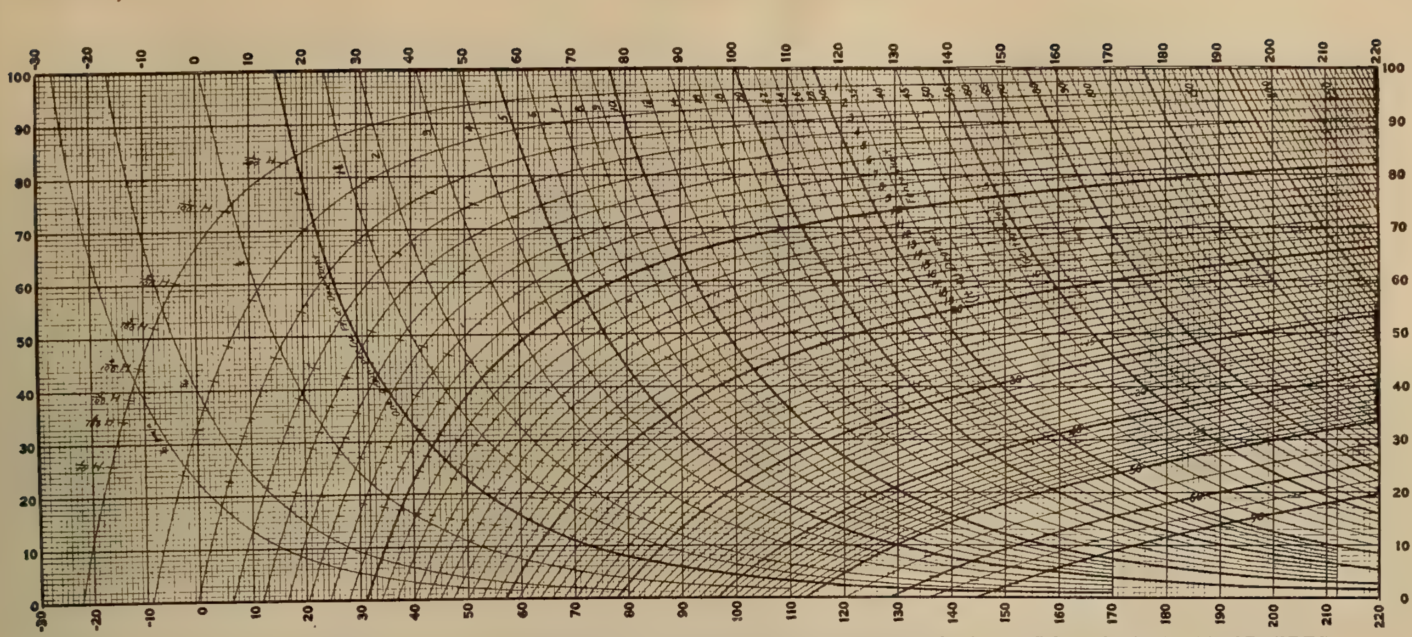


FIG. 1. HUMIDITY DIAGRAM FOR DETERMINATION OF ABSOLUTE HUMIDITIES, DEW POINTS AND VAPOR PRESSURES: ALSO RELATIVE HUMIDITIES BY MEANS OF WET-AND-DRY BULB THERMOMETER, FOR ANY TEMPERATURE AND CHANGE IN TEMPERATURE

the temperature reading at 100 per cent relative humidity is the dewpoint.

If we wish to find the dewpoint for an atmospheric condition of temperature = 90° F.; relative humidity = 65 per cent, we follow the chart as follows: At the intersection of the lines indicating 90° F. and 65 per cent relative humidity (indicated on the chart by the letter A), we find a heavy curve line rising toward the left, stopping at the top of the chart at 77° F., the dewpoint of saturation temperature for that atmospheric condition.

PRINCIPLE OF HUMIDITY CONTROL.

It has just been shown that, if air is cooled to the dewpoint temperature for a particular atmospheric condition and is saturated, the amount of water vapor retained is fixed. It is important that this shall not be changed, or else a different humidity will be secured. Consequently, the air must not be cooled below the dewpoint temperature after being saturated, or some of the water vapor will be condensed out. Nor must moisture enter the air from outside sources after the air is saturated, or higher humidities will result. After the water-vapor content of the atmosphere has been controlled by cooling to the dewpoint temperature and saturating, the air is passed through heating units which bring it to the temperature desired, and the conditions have been controlled.

After entering the room, the air is subject to changes. Heat and moisture may be absorbed or given off by the material in the room, or may pass through the walls of the room. Since, in either case, the air must be conditioned again in order to keep the room under control, the air is circulated through the controlling apparatus again and brought into the room to compensate for the heat and moisture changes. The capacity of the controlling apparatus must be large enough to move the air as fast as changes take place in the room.

CONTROL OF THE DEWPOINT.

The dewpoint temperature is controlled by passing the air through a spray of water, which both cools and saturates the air. Fig. 2 shows the arrangement of the sprays in the chamber. A line of spray nozzles is placed about 12 inches below the top of the chamber, and water is forced through the nozzle at about 40 pounds pressure, giving a fine spray, which drives the air through the chamber. The water leaving the nozzles must be several degrees cooler than the dewpoint temperature, since it absorbs heat in cooling the air that is passing through. The temperature of the spray water can be regulated by a mixing valve, supplied with hot and cold water at the same pressure, which can be set to supply water to the sprays at any intermediate temperature.

The spray chamber is of waterproof material, preferably of non-rusting metal, and is provided at the bottom with a drain, through which the spray water is carried off. Since the temperature inside the spray chamber, namely, the dewpoint temperature, is lower than the room temperature, the front of the chamber is covered with a heat-insulating material to prevent the cooled air from absorbing heat before it leaves the chamber.

The lateral depth of the spray chamber is kept small enough to prevent back currents of air, which might carry a mist out of the top. The spray carries the cooled and saturated air to the bottom of the chamber where it passes through baffles. These baffles, fitted with sharp lips, remove the entrained moisture from the air, preventing supersaturated air from passing through.

The temperature at which the air leaves the baffles determines the amount of moisture retained, and a thermometer, placed in the path of the air as it leaves the baffles, measures the dewpoint temperature. By placing the thermometer at this point, errors due to heat losses in the spray chamber are eliminated.

The air is carried from the baffles to the heating coils by ducts, which must be waterproof, to prevent moisture entering from outside sources, and must be as warm as or warmer than the dewpoint temperature to prevent condensation as the air passes through. If the duct is warmer, the air will absorb heat, and the water vapor is certain to be retained. These precautions are taken to bring the saturated air from the spray chamber through the heating coils without a change in water-vapor content.

TEMPERATURE CONTROL.

Upon leaving the duct, the air pases through heating coils of sufficient capacity to bring the temperature up to the value desired for the room. The air absorbs heat and, as it rises, influences a thermostat placed 3 or 4 feet directly above the heating coils. The thermostat operates on the steam supply, allowing sufficient steam to enter the coils to heat the air to the desired temperature, and cutting off the supply when the temperature gets too high. The temperature of the air in the room is controlled within one degree of the setting on the thermostat. The thermostat can be set for any temperature within a practical range, and this makes flexibility of control possible.

The radiation of heat and the passing of moisture through

the walls vary with seasonal changes, affecting the conditions of the atmosphere within the rooms. This may be compensated for in part by using small heating coils during warm weather and larger coils during cold weather. The heating unit may be broken into subunits, and only as many subunits as are necessary need be used. Thus closer control is made possible.

CIRCULATION.

The conditioned air is circulated by two means: first, through the force of the sprays; and, second, through the room by fans, placed above the heating unit, which take the air as it leaves the coils and distribute it through the room. If the room is being used to control the moisture content of wood, the air may largely be recirculated and only a small supply of fresh air need be drawn in. The heat and moisture losses in such a room are ordinarily small, so that it is not necessary to condition the air so often, and control is more easily maintained.

operating the steam valve by compressed air, is placed on the wall. The dewpoint thermometer is located above the baffle box. The dewpoint temperature for this particular room condition was only 2.5 degrees below room temperature, and no insulating material was necessary on the spray chamber.

Fig. 5 shows a wooden spray chamber, lined with waterproof paper. The front is removed and Fig. 6 shows the sprays in operation. The nozzles are set to give a fine spray, and not a mist. The water is passed through goosenecks to prevent grit from entering the nozzles.

DESIGN OF THE APPARATUS.

In workshops it is desirable to change the air once every 10 minutes. Experiments on spray nozzles have shown that, with a comparatively free air passage, one spray will move 80 cubic feet of air per minute. One spray nozzle will be necessary, then, for every 800 cubic feet of space in the room. The rest of the controlling apparatus is designed to conform to the number of sprays used. The heating coils must have

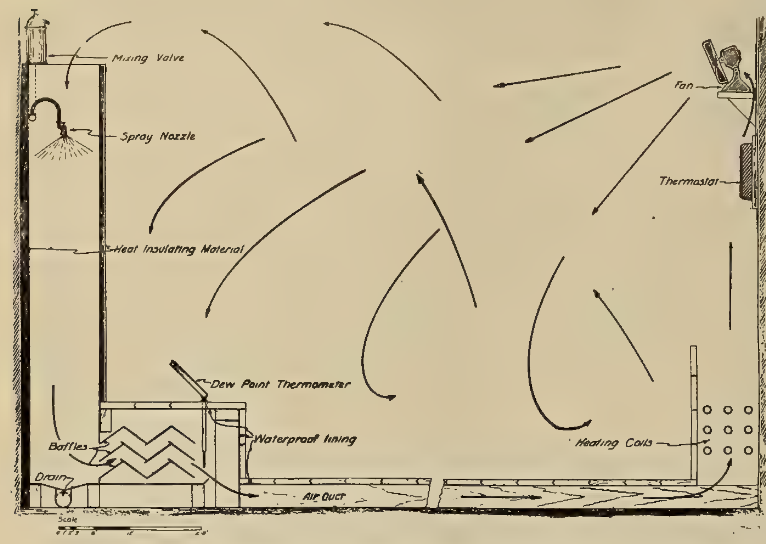


FIG. 2. ARRANGEMENT OF HUMIDITY CONTROL APPARATUS

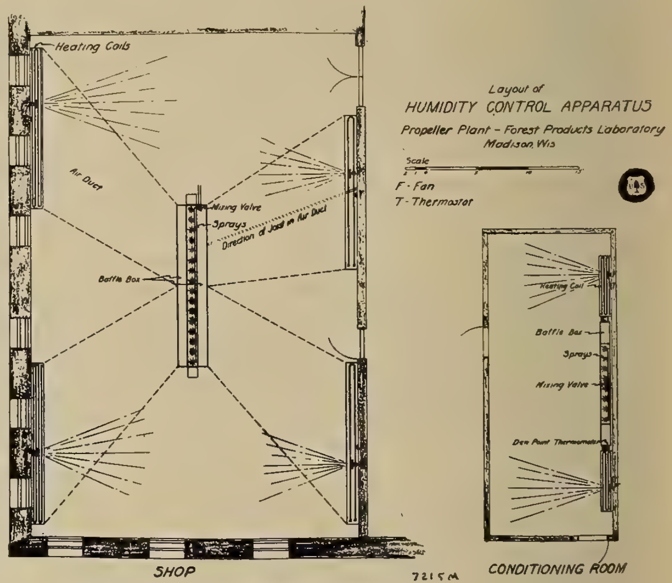


FIG. 3. PLAN OF SHOP AND CONDITIONING ROOM

It is more difficult to control atmospheric conditions in rooms where workmen are engaged, for doors are frequently opened, allowing unconditioned air to enter, and a generous supply of fresh air must be introduced for breathing. The additional changes caused by machinery and radiation require a somewhat frequent conditioning of the air.

ARRANGEMENT OF THE APPARATUS.

Fig. 2 shows diagrams of the humidity and temperature controlling apparatus. The essential parts of the apparatus are named and the path of the air is shown by arrows. Fig. 3 gives a plan of a shop room and of a storage or stock-conditioning room, showing the position of the spray chamber, heating units, and accessories.

In the shop room the air is drawn into the spray chamber from near the ceiling and is carried from the baffles to the heating coils through a duct under the wood floor. The duct, which opens out fanshape to offer least resistance to the flowing air, is painted on the bottom and lined on top with waterproof paper. Double sash windows have been put in to reduce the radiation. Fresh air is drawn in from the outside through a conductor pipe leading into the spray chamber. The arrangement in the storage room is much the same as in the shop room, except that the ducts are placed along the wall at the end of the spray chamber.

Fig. 4 shows a photograph of one-half of the metal spray chamber. The heating coils are enclosed in a wood box to prevent air from passing into the room before it is properly heated. The mixing valve, with hot and cold water supply pipes, is shown above the spray chamber. The thermostat,

capacity enough to keep the room at the desired temperature when radiation through the walls is greatest and to heat the cooled air as it leaves the baffles.

When the relative humidity desired is 60 per cent or more, the dewpoint is less than 15 degrees below the room temperature, and only a small heating capacity is required to heat the air as it leaves the baffles. As the relative humidity becomes lower, the difference in temperature increases rapidly and more heating capacity is required. The largest factor to be considered in calculating heating capacity is the amount of radiation through the walls of the room. The greater the radiation, the oftener must the air be conditioned in order that control may be maintained.

Storage rooms may be made with insulated walls so that the air need not be conditioned so frequently. Heat and moisture changes are not nearly so rapid as in shop rooms, and uniformity of control is more easily kept.

Water must be supplied to the nozzles at a pressure of 40 pounds in order to form a proper spray and to move the air through the apparatus. In order that the hot and cold water may both be supplied to the mixing valve at the same pressure, a part of the cold-water supply is diverted through a heating tank and then sent to the mixing valve.

Painting the walls of rooms prevents rapid change of moisture through the walls, and this, again, makes it easier to maintain control.

OPERATION.

Because of its ability to maintain uniform conditions, acting as a humidifier or as a dehumidifier, as the conditions

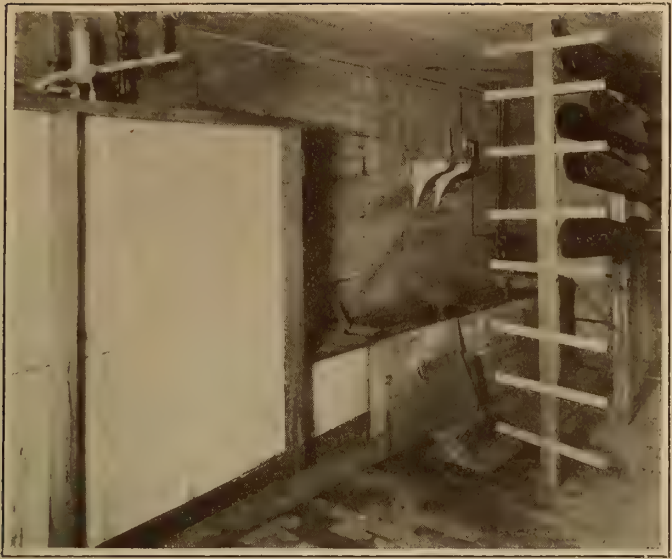


FIG. 4. ONE-HALF OF THE METAL SPRAY CHAMBER, MIXING VALVE SHOWN AT THE LEFT

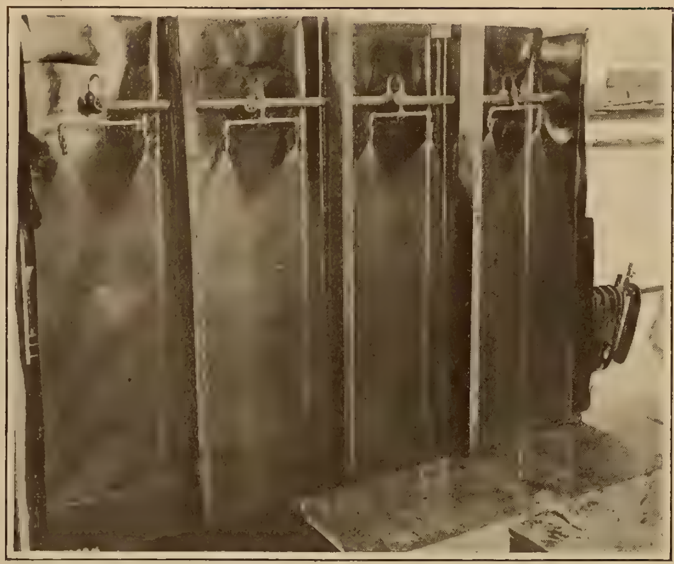


FIG. 5. WOODEN SPRAY CHAMBER LINED WITH WATER-PROOF PAPER

demand, this type of control is particularly valuable. If the air enters the spray chamber with a humidity above the desired value, the excess moisture is condensed out in passing through the sprays. If the air enters the spray chamber with a low humidity, moisture is taken up in passing through the sprays, and in either case, the air has been conditioned to the proper value when it leaves the baffles. Whether moisture is entering or leaving the room through the walls, or whether moisture is being absorbed or given off by the material in the room does not affect the operation or the control, for, in either case, the air is automatically conditioned back to the desired temperature and relative humidity, without any change or regulation of the controlling apparatus.

In Fig. 6 is shown an autographic 24-hour record for a storage room 12 feet by 30 feet by 8 feet, controlled by this system. The thermostats have kept the temperature within a degree of the desired value, and the sprays have kept the dewpoint constant, resulting in a uniform relative humidity.

An occasional inspection of the apparatus for small adjustments is usually all that is necessary. The water supply should be free from grit or scum which clog strainers and nozzles and prevent them from operating properly.

The type of installation can be suited to conditions. Where the apparatus is desired as a part of the permanent equipment, it is best that it be made of non-rusting metal. For temporary purposes only, a wooden chamber lined with water-proof paper is satisfactory. The cost of operation is almost entirely that of water supply. A work shop, 30 feet by 50 feet by 11 feet, requiring a change of air every 10 minutes, would call for a controlling apparatus with 20 sprays consuming 400 gallons per hour. Where cold water is cheaply obtained, this type of control becomes a commercially economical installation.

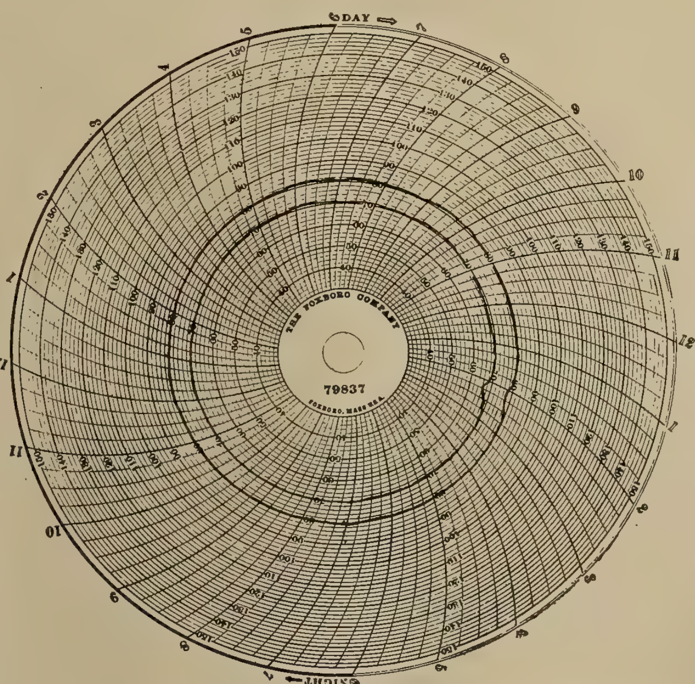


FIG. 6. AUTOGRAPHIC 24-HOUR RECORD FOR A STORAGE ROOM

The application of humidity control to commercial fields has extensive possibilities. In wood-using manufacturing establishments, where material is cut accurately to dimension, the best results are obtained when the wood is kept at a uniform moisture content after being cut, so that shrinking and swelling due to changes in moisture will have less tendency to prevent the parts from fitting together at the time of assembling.

In shops where humidity control is not practiced, even when the parts are assembled immediately, the effects of shrinking or swelling, due to unequal moisture contents, are not avoided, but become evident in the warping, checking, or even splitting of the assembly. When it is desired to minimize these effects, the wood should be conditioned before being cut to dimension.

Although kilns are instrumental in removing moisture from wood, the moisture content throughout a load may not be uniform, and the differences in moisture content on leaving the kiln may be great enough to cause trouble in the manufactured article. If the stock of material is left in storage rooms in which the conditions are controlled, the moisture content becomes uniform, and subsequent unequal shrinkage or swelling is minimized.

The conditioning of shop rooms has a double purpose. Primarily, it affords control of the moisture content while the material is being worked up into shape. Even if the material is conditioned in a storage room, the conditioning must be continued in the shop if shrinkage or swelling is to be avoided. Controlling shop conditions continues the process of making the moisture distribution uniform. As a secondary result, conditioning a shop room increases its healthfulness. Dust in the air is carried into the spray

chamber and washed away with the waste water, giving a supply of clean air in the shop. Also, the temperature of the shop room may be maintained at a uniform degree and in summer, when high temperatures prevail outside, the shop may be kept at lower and more comfortable temperatures.

Although developed primarily for use in wood-using establishments, first in the dry kiln and then in shops and storage rooms, the field of this humidity and temperature control is by no means restricted to wood-working plants. It may be used wherever for any purpose it may be found desirable to maintain definite, uniform atmospheric conditions.

Among others, conditioning control has been found beneficial both to the material being manufactured and to the health of employes in the following places: Finishing and drying rooms, textile mills, munition factories, chemical factories, foodstuff factories, rubber factories, and tobacco factories. There are numerous other important industrial plants in which control of atmospheric conditions would be beneficial and the type of apparatus described in this article would probably be applicable to many of them.

General Applications of Selenium—1*

Its Utilization in Biological Chemistry and in the Glass and Rubber Industries

By Louis Ancell

AT first glance selenium and its applications hardly seem to be properly included within the domain of industrial chemistry properly so-called. However, certain new applicaions of this metalloid either already accomplished or by way of accomplishment in biological chemistry, in chemical industry, and especially in electrical technology make it a matter of interest to consider in a single article the properties and applications—at once so original and so varied—of this substance so scantily found upon the earth and yet so well-known because of the numerous scientific works devoted to it.

We will examine in order:

1. Selenium and its principal properties.
2. The utilization of selenium in biological chemistry.
3. The employment of selenium in the glass and rubber industry.
4. The applications of selenium in electrical technology, especially in the chemical industry, the military art, the photography of words or the reproduction of sounds by photography, wireless telephony, television and the transmission of images to a distance, and photometry.
5. The future of selenium and its applications.

Selenium is best known by its curious property of having its electric conductibility influenced by exposure to light, but it is none the less true that it is capable of various chemical applications of an industrial nature, and in this respect it offers a wide field for research.

PRINCIPAL PROPERTIES OF SELENIUM.

Manufacture.—Selenium is a metalloid belonging to the sulphur family whose atomic mass is 79.1, the figure adopted in 1898 by the International Commission of Atomic Weights. It was discovered in 1817 by Berzelius in the sediment of the lead chambers of Gripsholm, the treatment required being long and complicated. The present process as applied in one of the principal chemical works in France, consists in extracting the selenium from the residuum left by the treatment of the Hautmont (Nord) pyrites, titurating about 15 per cent. These residues are first treated with *aqua regis* which transforms the selenium into selenious acid. This latter compound is reduced by suphurous acid which precipitates the selenium in the form of a powder which is then washed and dried. Finally the product is melted and run off in the form of cylinders in copper molds immersed in water; it is placed upon the market in this state.

Selenium can also be extracted from zorgite and the impure double seleniide of copper and lead which is tolerably abundant in the Argentine Republic, and which contains nearly 30 per cent of selenium. In this case the pulverized mineral is treated with *aqua regis* which transforms the selenium into selenious acid and the metals into chlorides. The excess acid is driven off by evaporation and the sirupy liquid is then diluted with water in order to precipitate the major portion of the chloride of lead. After filtration the clear liquid is treated by a current of sulphurous gas which precipitates the selenium in the form of red flocculae. It is filtered again and washed with hydrochloric acid and with water to eliminate the last traces of chloride and is then melted in black lead crucibles and run off either in sheets or in cooled molds.

It is of importance, especially with respect to the physical applications of selenium, to purify it in order to eliminate the sulphur and the tellurium which it always contains. One of the most practical methods of doing this appears to be that of Divers and Shimosé[1] since this permits a rapid and practically complete purification. In this process the selenium is dissolved in boiling concentrated sulphuric acid and is thus transformed into selenious acid. The cooled liquid is afterwards diluted with water and then treated with a current of sulphurous gas which precipitates the selenium. The red powder obtained is separated by filtration, washed with water and alcohol, and then placed to dry upon plates of porous porcelain. In this manner the traces of tellurium are completely eliminated and the purified product contains only slight traces of sulphur which are practically negligible.

Selenium presents itself in various allotropic conditions which are of interest because of their peculiar properties. A first form of these includes vitreous selenium, amorphous selenium, and colloidal selenium; a second form is red crystallized selenium; and a third form is grey or metallic crystallized selenium which is differentiated from the other two forms by the fact that it alone is completely insoluble in carbon disulphide.

Vitreous Silenium.—1. In its first form selenium melts at 220° C.; and becomes soft and viscous at about 60° C.; if it is then cooled again it becomes hard and brittle and is then called *vitreous* selenium. This is black in color with a conchoidal fracture and when powdered it is grayish if the powder is coarse, and red if it is very fine. In the course of our researches (begun in 1909) concerning this variety, we found that vitreous selenium melted at 220° C. and when cooled rapidly *under pressure* is suddenly transformed into a new variety, *violet* gray in color and composed of fine crystals which are highly sensitive from the photo-electric point of view, but whose stability leaves much to be desired. In order to utilize and preserve this extra sensitive variety, consequently, it is advisable to add to it a certain quantity of vitreous selenium in order to distribute uniformly the violet gray crystals in a sort of solid and stable solution of vitreous selenium. The latter constitutes a substratum which cements and re-

*Translated for the SCIENTIFIC AMERICAN MONTHLY from *Chimie et Industrie* (Paris).

[1]Divres and Shimosé, Chemical News, Vol. 51, p. 199, 1885.

unites the various sensitive crystals of the upper stratum which is exposed to the light. Accepting this explanation which appears to be more or less plausible but which is given here merely by way of suggestion, we succeeded in discovering a process which enabled us to make a practical preparation of selenium cells which are extremely sensitive even to the feeblest luminous intensities. On the other hand the slightest impurity (particularly metallic powders) constitutes a sort of poison, which while activating the transformation causes the destruction of the unstable variety of sensitive crystals and transforms the mass of selenium into a variety which is as good a conductor as a metal, and is furthermore insensitive to light.[2] This modification is also capable of being produced in the cells by the mere lapse of time, or under some external influence such as the sudden passage from heat to cold or vice versa, a somewhat violent shock, or a sudden break of a circuit containing a self-induction and the cell. It is obvious, therefore, that very great precautions must be taken in the preparation as well as in the employment of this variety of highly sensitive selenium.

Amorphous Selenium.—Also included in the first form of the allotropic state is *amorphous selenium*, which is obtained in the state of a red precipitate through the reduction of selenious acid by sulphurous gas. Heated to a temperature of 40° C. to 50° C. this red powder becomes agglomerated into a soft mass, which becomes hard and brittle when cool.

Colloidal Selenium.—Colloidal selenium, the third variety of this first form is obtained by mixing two very dilute solutions of selenious and sulphurous acids. The mixture, which is yellow at the beginning, gradually turns red and finally deposits a red powder of selenium, insoluble in water, which becomes agglomerated at 40° C to 50° C., and is transformed like the amorphous selenium, and under the same connditions, into vitreous selenium.

Crystallized Red Selenium.—2. This constitutes the second form of the allotropic state. It is not sensitive to light and is obtained by the slow and careful evaporation of a sulphocarbonic solution of selenium.

Crystallized Selenium.—3. Finally *gray or metallic crystallized selenium* is obtained by the action of heat upon anyone whatever of the foregoing varieties. This according to Saunders[3] is the form which is most stable at all temperatures below 217° C. to 220° C., the point of fusion of selenium. This variety is not soluble in the sulphide of carbon, no longer exhibits a conchoidal fracture, and assumes a granular aspect; it is a conductor of electricity especially under the influence of light or of a slight elevation of temperature.

The density of selenium varies from 4.259 to 4.805 in the different varieties.[4]

The average boiling point of selenium is about 690° C. as proved by Daniel Berthelot.[5]

Vitreous selenium which is not a conductor of electricity is transformed as we have seen under the influence of heat alone into the metallic conducting modification, or under the combined influence of heat and pressure[6] into a modification which is an even better conductor of electricity than the ordinary metallic variety. This conductibility is highly augmented when the selenium is mixed with metallic powders. It is well to note, also, that the heating of selenium in order to obtain a highly sensitive variety should be made with a care to exclude both humidity and a direct gas flame.

The augmentation of the conductibility appears to be due to the presence of metallic seleniides according to the researches of a number of authorities (Graham Bell, 1880, Schuller, 1883, and Bidwell, 1891), corroborated by our own investigations. When these seleniides are formed upon the surface of wires or of sheets the conductibility is normal; when, on the contrary, a few fragments of metallic powders or of vitreous selenium which has been melted and previously rubbed upon the metal, are mixed with pure vitreous selenium the latter is transformed under the influence of heat alone, or still more rapidly under the combined influence of heat and pressure into a variety of selenium which is so good a conductor that its conductibility approximates that of a metal. A cell sensitized under these conditions is practically unusable. As a result of this fact in constructing selenium cells it is necessary to employ a support which contains not the slightest metallic or conducting particle and which is incapable of absorbing humidity. Porcelain and certain varieties of steatite are suitable for this purpose.

The nature of the metal employed as an electrode does not appear to have any perceptible influence upon the conductibility of the selenium. Platinum has the advantage of not being readily oxidized and copper or even brass can be readily used in practice.

We may mention here that a collation of all the researches devoted to selenium has been undertaken in various quarters (Amaduzzi, 1904; Marc, 1907; and Ries, 1908). The Russian journal *Questions de Physiaqe* for 1910, page 175, contains a résumé of the principal results obtained.

THE UTILIZATION OF SELENIUM IN BIOLOGICAL CHEMISTRY.

Silenium alone has hitherto found but little employment in chemistry worth mentioning from the industrial point of view. But it has been used for several years in the form of cutaneous injections in mice at the Institut Pasteur by M. Borel, in certain bilogical researches relating to the development of cancer. It has been thought that the toxicity of selenium and of its salts might occasion a retrogression of the tumors. As a matter of fact, however, the experiments made upon mice have not yielded conclusive results and no tests have been made upon human subjects. So far as we know no new researches have been attempted along this line.

SELENIUM IN THE GLASS AND RUBBER INDUSTRIES.

Selenium has been employed in the manufacture of glass, giving a pale violet color and more recently in the vulcanization of rubber.

In the first case the selenium is incorporated with the molten glass, either in the form of vitreous selenium or under that of selenites which undergo reduction during the manufacture of the glass.

As regards the latter use experiments have been conducted in Boston since 1913 by the Simplex Wire and Cable Co. In these experiments a quantity of selenium equal to that of the sulphur employed in ordinary vulcanization is heated to 150° C. for two hours' time. The product obtained is somewhat less solid from the mechanical point of view than the rubber vulcanized by sulphur. On the other hand it is possible to obtain selenium rubbers which are soft and very durable and which exhibit excellent resistance to normal traction and extension by heating the selenium to 135° C. together with certain organic accelerators for a period of time twice that of ordinary vulcanization.

This selenium caoutchouc does not deteriorate in spite of the sensitiveness of selenium to light.

(To be continued)

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[2]Louis Ancel, Bull. de la Soc. Chimique (Chemical) de France, fourth series, Vol. xvii, p. 10, 1915.

[3]Saunders, Jour. of Phys. Chem., Vol iv, p. 423, 1900.

[4]Schaffgotsch, Journ. f. prakt. Chm. Journal of Practical Chemistry), Vol. xliii, p. 308, 1848.

[5]D. Berthelot, C.R. Ac. Fr., Vol 134, p. 705, 1902.

[6]Louis Ancel, Bull. Soc. Chim. l.c.

NEW USES FOR "CELLON."

LIQUID "Cellon" can be used for impregnating textiles, etc., or for making insulating tape. In this latter form it can be taken from the round box in which it is wound up, even in the moist condition, and allowed to harden in air.—Abstracted through *The Technical Reviews* from *Mitteilungen des Reichsbundes Deutscher Technik*, Aug. 30, 1919.

Modern Glass Manufacture

American Methods of Making Cut Glass

By J. F. Springer

GLASS is, I think, one of the most wonderful of all the materials prominent in modern civilization. When one considers the beautiful clear transparency attainable with glass and the readiness with which the transparent substance may be shaped to an infinity of forms, he begins to realize some of the remarkable qualities. When one goes further and takes into account the immunity that glass enjoys with respect to the attacks of pretty much all acids and chemicals of every sort, he is still further impressed. The foregoing qualities, taken in connection with its cheapness, make of it one of the most popular and useful of all the materials used for household, laboratory, pharmaceutical and building purposes. Tableware, chemical appliances, medicine bottles, window-glass—all these are prominent examples of the application of glass. This material is usually very fragile, brittle and hard. But those qualities vary between limits that are fairly wide apart. Glass is ordinarily, but not always, transparent. Because of such variations as those noted, it is not so easy to give a descriptive definition that will sufficiently distinguish it from other substances. There is, however, one quality which assists us in marking it off and giving it a place of its own. Glass is structureless. Doubtless, from the point of view of chemistry, there is structure. Generally, minerals and bodies of the types associated with life processes have a crystalline or other structure. With glass, there is apparently no such thing as a structure that can be made evident by the unaided eye or by means of the microscope. Glass seems, in fact, to be as structureless as any of the liquids—as water, for example. If one chooses to regard glass as a "congealed liquid," he may do so, provided he does not assume anything in the nature of crystallization. However, W. Rosenhain, an authority on the manufacture of glass, says: "All glasses are capable of undergoing the change to the crystalline state when kept for a sufficient time at a suitable temperature. The process which then takes place is known as 'devitrification,' and sometimes gives rise to serious manufacturing difficulties."

In general, glass may be viewed, when in the molten state, as a mutual solution of silicates and borates. The condition of mutual solution continues throughout ordinary cooling, so that one is privileged to regard glass in the cold state as a congealed solution. The substances which enter into the composition of glasses have, naturally, their individual melting points, so that if the temperature of a mass of molten glass be maintained for a period at a little below the fusion point of one of the constituents, that substance may often begin to solidify alone and its crystals to take form in the mass. This is a devitrification process, and is something to which certain glasses are especially subject.

LAYING ON THE PROPOSED PATTERN WITH A PENCIL

It is a fact well recognized that the presence of impurities in a substance often tends to lower its point of fusion. This is true of glass. Pure silica may be made into a glass of a very valuable kind, but the temperature necessary to effect the fusion of the pure substance is so great that the ordinary furnace of the glass-maker is quite inadequate. The laboratory furnace heated by the oxy-acetylene flame is, however, usable; although a less perfect silica ware is producible by means of the electric furnace.

Glass is dependent upon the materials which are brought together in the mass which is reduced to the molten state in the crucible employed—but it is not entirely dependent upon these materials. That is to say, during the period of melting, the molten mass will absorb from the fire-clay crucible. The mutual solution constituting the molten mass tends, it is understood, to a condition of saturation, so that it will seek to rectify any deficiency by absorptions from the containing vessel. Because of this fact, it is customary to choose the precise character of the material in the body of the crucible with a view to such absorptions. For example, if a crucible charge is rich in silica, an acid substance, but deficient in bases, the mass when molten will naturally dissolve basic material from the crucible walls. Similarly, if the charge is poor in acid materials, it will tend to absorb substances from the fire-clay container.

A certain glass, which is rather difficult to make because of its considerable fusion point, is termed "combustion tubing." This tubing meets the desire for a glass capable of retaining its hardness without much loss when it is heated to a red heat. Instances of such glass are the varieties known as Jena special thermometer glass, and the French "Verre dur." The highest qualities of refractory glass are competent to resist temperatures up in the neighborhood of 900° F. Combustion tubing is manufactured from a glass containing a much reduced percentage of basic material. The alkaline material is especially minimized. What basic material is used is selected from the highly refractory bases, such as lime, magnesia, etc. Special furnaces are needed to effect the melting.

The molten mass in the crucible or furnace is removable in three ways—and, it seems, in three ways only. These are (1) by means of a ladle; (2) by pouring, and (3) by gathering. The most objectionable of these is the first. The metal of the ladle communicates impurity both to the glass withdrawn in it and to the main body into which it is dipped. Further, the cold ladle carries with it a considerable quantity of small particles of air; or, perhaps it would be more

PARAFFINING THE INSIDE OF A BOWL BEFORE DIPPING IT INTO THE ETCHING BATH

CUTTING OUT THE PATTERN IN A CLARET DECANTER WITH A CARBORUNDUM WHEEL

correct to say that the ladle carries in air which manifests itself as small bubbles in the body of the glass. A hot ladle might perhaps avoid this phenomenon, but it would introduce another objectionable result—the adherence of glass to the metal. This disadvantage must be ranked by the manufacturers as very undesirable indeed, since cold ladles are in such general use, despite the air-bubbles and the additional objectionable feature that the cold ladle chills the glass in immediate contact with its inner surface. Ladling is, in general, confined to those cases where the glass is to be used for such purposes where the bubbles will not find objection. Such glass is, naturally, inferior in quality. It is, however, quite serviceable for certain applications—especially window-glass of inferior grades. Ladled glass is usually rolled. That is, it is thrown upon a level surface and there rolled by a roller which passes over the surface; or it is passed between two rollers set in fixed positions and is received subsequently to emergence by a moving table. This latter variety of rolling is especially used in producing figured rolled plate, the figures consisting of indented patterns.

The higher qualities of glass are removed from the crucible or furnace by pouring or gathering. Thus, cut glass is made from material withdrawn by one or other of these methods; and seldom or not at all from material removed by the ladle. The explanation is simple. When glass is cut for the purpose of ornamentation, a greater or less amount of work is put upon it which tends to increase the price. Consequently, the expense means close scrutiny upon the part of the customer. Pouring is accomplished by tipping the containing crucible or pot. This receptacle may be the one in which the original melting took place; or it may be a special pot to which the glass has previously been transferred. In either case, the highly heated pot with its charge of molten glass may require to be taken out of the furnace by mechanical means. Overhead machinery may now be called into action for the purpose of transporting the pots to the spot where the pouring is to take place. The pot is tilted and the glass runs out. What now becomes of the glass depends upon the particular method of manufacture. In one procedure, the molten glass flows from the pot upon a rolling table and a roller is passed along to roll out the pool into a sheet or thin slab.

Instead of pots, it is often, not to say generally, preferable to use what is known as a tank furnace. In a work on glass manufacture dated 1908, the author stated with reference to tank machines: "None of these devices have, so far as the writer is aware, found their way into practice." In a U. S. Government report dated 1917—only nine years later—it is stated: "The tank furnace has generally displaced the pot furnace. The advantages claimed for it are increased production, continuous operation, regularity of work, more efficient utilization of the heat and flame of the furnace, greater durability, and better glass production, in that the molten glass in a tank can be maintained at or near a constant level, which makes gathering easier."

There are machines which dispense with gathering and substitute pouring or flowing. Thus, there is a type of mechanical device which is adapted to receive molten glass into molds which revolve. In the case of a certain machine of this type, the revolving molds will pass below a certain point. Here there will be a projection from the tank. A stream of glass flows vertically downward as the molds pass. There is, at one side of this vertical stream, a cup-shaped cutter, and at the opposite side, a blade. The cutter and the blade are operated horizontally in such way as to come together, after the manner of the blades of a pair of scissors. The result is that the vertical stream of glass is cut off. It continues, however, to flow into the cup-shaped cutter instead of passing on into the mold. The cup affair is turned over part way, but not so far as to prevent the glass from the tank from flowing into it. The next mold now comes into position, and the glass caught by the cup device is delivered to the mold. "The stream of glass from the tank then flows directly into this new mold." The cycle of operations is repeated as each mold comes to position. These machines are not used for all purposes. In fact, their applications appear so far to be rather limited. They are particularly suited to jars and to bottles with wide mouths.

The third method for removing glass from the furnace or crucible proceeds by using a heated iron rod or tube. The rod or tube is introduced into the mass of liquid glass and gathers a small amount. It is then withdrawn and the glass permitted to cool to the point that it is able to support its own weight. The rod or tube with its ball or knob of partially cooled glass is now introduced into the molten mass and

additional material gathered. The cooling is repeated. By going through this procedure a number of times, a considerable amount of glass—up to 30 or 40 pounds—may be gathered. The process is suitably known as gathering.

Perhaps the most interesting side of the glass industry is that which is concerned with the manufacture of cut glass. The interest of Americans will not be diminished by the fact that the heavy cut glass manufactured in the United States is thought to be superior to similar cut glass manufactured elsewhere in the world. Superiority is claimed particularly in respect to the crystal brilliancy and to the sharpness of the cutting. Oxide of lead and potash have been largely employed in making the glass. The potash facilitates the fluxing of the other materials which enter the furnace. Both the potash and the lead oxide produce "a prismatic effect with high refractory qualities." So beautiful and artistic are the best grades of American cut glass that its reputation has spread throughout the world. Permit me to repeat from a grave Government document a story illustrative of this point: "Some people accustomed to traveling abroad are inclined to believe that cut glass from Europe is superior in quality to the best American product. An American manufacturer of cut glass who has a salesroom in New York City informed an agent of the Bureau of Foreign and Domestic Commerce that two years previously a wealthy woman called at the factory and showed him a glass article which had been broken. She stated that she had purchased the set at one of the fine shops in Vienna and inquired whether this company had not imported a similar set from which the broken article could be duplicated. The manufacturer examined it closely, and informed her that his salesroom in New York had a similar article in stock and that it would be shipped to her. The cut-glass products of this factory had been exported in considerable quantities to Austria-Hungary, and the broken article that was duplicated had really been made in the American factory."

Cut glass is manufactured from blown blanks or else from pressed or molded blanks. The latter type of blank may come from the press-molds with a considerable part of the desired pattern already formed. There are, naturally, various grades of quality. Where the cutting is shallow and has been effected merely by the use of the common unpolished wheel engraving, the cost of certain small articles may be such as to permit their sale in 5 and 10 cent stores. Then, on the other hand, the designs may be most elaborate and belong to the class known as "rock crystal." The cutting and engraving of such articles as vases, stem ware, colognes, etc., is generally carried out on blown blanks. Apparently, the principal reason is that such forms are unsuited for production by the mold. Where the form is open—that is, where the pieces are bowls, plates, etc.—the pressed blanks are usually employed. As to designs, it is said that there are many more original designs used for American cut glass than for European and that many American designs are taken abroad and there initiated. Going back to the normal period before the outbreak of the Great War, one learns that Europe imported American cut glass in considerable quantity. The countries to which the exports went included "countries that produce deep-cut glass and that have high duties on their imports."

In typical high grade manufacture, there are three principal operations. First, the cut is made by means of a steel wheel. The glass article is held against the rotating wheel and sand and water are poured on the wheel. Second, the article is held against a rotating stone wheel. This wheel smooths out the rough cut made by the steel disk. Two varieties of a Scotch stone known as Craighleith are employed. One is black in color and is softer than the other which is white. The soft black stone is preferred. Third, the article is held against a rotating felt wheel. The effect here is to produce a polished surface. The initial or roughing operation is often eliminated by the use of suitably figured blanks produced by a press-mold. This procedure effects also another saving. That is to say, it is then unnecessary to mark the pattern on the blank. However, the production of figured blanks was—and perhaps is still—accomplished by a patented process. Plain blanks had to be used by factories not participating in the patent. These were produced by iron pressure-molds or else blown in the ordinary way.

American methods differ somewhat from European. In general, in the United States, a big manufacturer will use different workmen for the three operations. In Europe, one man often carries out all three. Naturally, the American workman becomes highly expert on his single operation. Where the lines of the design have a considerable radius of curvature, it is permissible to use large wheels. There is an American tendency to favor such designs rather than those which contain sharp curves for which small wheels must be employed. American manufacturers use, in the smoothing operation, carborundum wheels and carborundum powder or grains to a considerable extent instead of following the European practice of employing stone wheels and sand. In Europe, the polishing is usually performed by means of the felt wheel and putty powder, while in America the article is dipped in acid subsequently to the smoothing operation. This preparation for the polishing is understood to result in the maintenance of the sharpness of cut; whereas, hand polishing with the felt wheel and putty powder tends to dull the cuts. The people in Europe have not been educated to the beauties of deep-cut glass ware, since—at least, until recent years—they preferred thin ware. But their education is progressing. An importer who sold Alsatian ware in the United States made substantially the following statement: "Five years ago I saw a window full of American deep-cut glass in Strassburg, the capital of Alsace-Lorraine. After that, I quit trying to compete in New York with American cut-glass."

ELECTROLYTIC COPPER.

"COPPER from Mine to Finished Product" is the subject of a very instructive brochure issued by the Anaconda Copper Mining Company. Much of historical interest is given as well as descriptions of commercial processes, and the following paragraphs on the electrolytic refining of copper are quoted:

"The electrolytic refining of copper may be divided into three stages:

"1. Melting the 'Blister Copper' and casting into 'Anodes' ready for the electrolytic tanks.

"2. 'Electrolytic' refining and obtaining 'Cathode Copper' of 99.98% purity.

"3. Melting of 'Cathodes' and casting the commercial shapes, such as 'Wire Bars' for wire mills, 'Cakes' for rolling mills, 'Ingots' for the brass and alloy manufacturers, etc.

"The 'Blister Copper' is delivered to the refinery in the form of slabs, weighing about 300 pounds. These are melted in reverberatory furnaces, known as 'Blister Furnaces' of 500,000 pounds capacity. The details of the operation are practically the same as in the 'Refining Furnaces.' In this melting process but little refining is attempted although some of the impurities are removed with the slag and the sulphur is practically eliminated. The copper is cast into 'Anodes' 37 $\times$ 28 $\times$ 1 5/8 inches, weighing about 500 pounds. A typical assay of 'Anodes' follows:

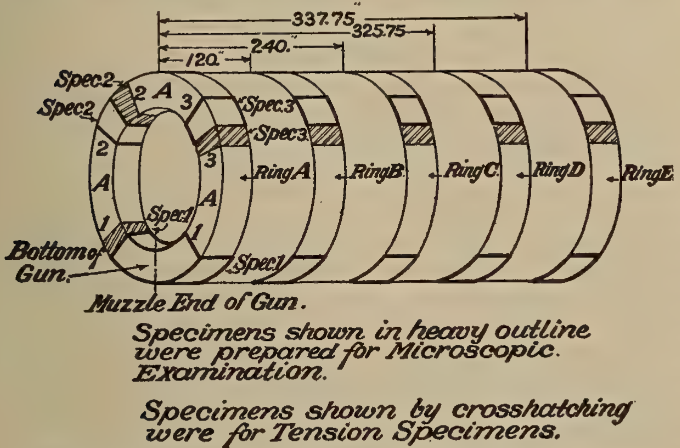
Copper—	99.25%	
Silver—	70.0	ounces to the ton
Gold—	.25	ounces to the ton
Arsenic—	.060%	
Antimony—	.052%	
Nickel—	.050%	
Lead—	.053%	
Iron—	.058%	
Bismuth—	.003%	
Sulphur—	.004%	
Selenium—	.008%	
Tellurium—	.038%	
Oxygen—	.100%	

The Death of a Big Gun

A Study in Erosion

By Arthur Benington

ARTILLERY of all sorts is short lived, and the bigger and more powerful the gun the shorter is its life. As in human life we should "count time by heart-throbs," so in common life we must count it in shots. A man is not living when he is in a state of coma, nor is a cannon living when it is not firing. A cannon begins to die with its very first shot, for this commences the work of erosion, which progresses with each shot until the bore of the gun is so worn that the projectile no longer fits it tightly; the gases generated by the explosion escape around the sides of the shell, failing to exert their full force upon it; the lands of the rifling are no longer true, and therefore cannot impart to the projectile the precise velocity of rotation that will carry it direct to its mark. Accuracy of aim is now impossible, and the gun's life of usefulness is at an end. It is true that it can be relined, and more than once, but this is a major



RELATIVE LOCATION OF RINGS IN THE GUN AND DISTANCE OF EACH FROM THE MUZZLE

operation for which the gun must be moved from the front and placed in hospital in the hands of expert surgeons, and the cost of relining a cannon three times is practically that of a new gun.

When we consider the enormous cost of cannon and how quickly the hard steel of its rifled bore is destroyed, we shall appreciate the importance of learning precisely what takes place within the firing chamber, in order that metallurgists may have the data necessary to a study of new methods of hardening and toughening the metal and thus prolonging the life of the gun. Rear Admiral Ettore Bravetta of the Italian navy has just published a book on artillery, in which there is a highly interesting chapter entitled "The Life and Death of a Gun." In this he states that before the war the British naval authorities considered guns eroded to the point of uselessnes, according to the following scale—the figures, of course, being averages: 100 mm. gun, after 739 shots; 127 mm., after 640; 152 mm., after 395; 203 mm. howitzer, after 254 shots; 234 mm. howitzer, after 204; 254 mm. howitzer, after 162; 305 mm. gun, after 149; 343 mm., after 102; 406 mm., after 83.

"Small artillery," continues Bravetta, "can fire from 4,000 to 7,500 shots; guns whose initial velocity is small, such as mortars and howitzers, last much longer than cannon of the same calibre, as they are subject to lower pressures and temperatures. Again, three shots with reduced charge equal one shot with full charge, as regards erosion."

Erosion manifests itself in the hardening and cracking of the rifled surface. The accompanying photographs, from the Bureaus of Ordnance of the U. S. Army and Navy show beautifully the appearance of this surface after a number of shots have been fired. The hardened layer is so thin that it has not been found possible to remove it for chemical analysis. The depth of this layer varies from 0.0004 inch close to the muzzle to 0.0015 inch at the beginning of the rifling, this in an American 12-inch gun that had been fired 239 rounds. The cracks, as is evidenced from the photographs, extend through the hardened surface layer and relatively far beyond it.

In the report of Gen. William Crozier, as Chief of the Bureau of Ordnance, U. S. A. for 1913, is a study of the gun just mentioned. From this five rings were cut, one at the muzzle, the others 120 inches, 240 inches, 325.75 inches and 337.75 inches, respectively, from the muzzle. From each of these rings "sections the width of each ring and of a length corresponding to about four grooves and five lands were cut." These sections are shown in the accompanying photographs, marked A, B, C, D and E. "The surface erosion was greatest in Section E (that nearest to the breech), and diminished progressively toward the muzzle end. In Section E there has been a very considerable flow of metal, and the cracks do not appear to be so numerous as in Section D. In Section D there are not only extensive transverse cracks, but also very extensive longitudinal cracks, the latter being particularly noticeable at the bases of the lands. In Section C there is no pronounced direction to the cracks, but the lands and the central portions of the grooves show a crackled appearance. In Section B the cracks are not so evident. There is some rounding of the lands, and the driving edge shows some cracks. In Section A the lands and the grooves are clean-cut, with cracks only on the firing edge of the lands."

The dimensions of these cracks vary irregularly, the greatest depth being in Section D, where six were measured as follows: 0.036″, 0.051″, 0.030″, 0.033″, 0.042″, and 0.029″. At their mouths the cracks varied in width from 0.015″ to 0.001″, and halfway back from 0.001″ to 0.007″. The cracks in Section C are only a trifle less deep than in Section D, but not nearly so wide. They get progressively smaller as the muzzle is approached.

There are three theories on any of which it is possible to account for this hardening and cracking of the rifled surface.

"In a general way," writes Admiral Bravetta, "one may say that it is produced by the action of gases at high pressure and elevated temperature upon the steel. Although this phenomenon lasts a very brief time, yet the cannon in firing absorbs a certain quantity of heat, limited to a very thin layer of steel on the surface of the bore. The local heating causes this layer to expand, but, as it is surrounded by the thick and relatively cold walls of the inner tube, such expansion cannot take place naturally, the limit of elasticity is overpassed and permanent distortion follows.

"When the pressure ceases and the temperature is lowered, the layer in question contracts and, as it has been crushed, its contraction produces a quantity of little surface cracks like those which create the value of certain precious Chinese porcelains called 'crackled.' This process continues with every shot, and each time the cracks become wider. As they increase they become so many tiny canals through which the hot gases penetrate and in their turn enlarge them. Continuing thus, the inner surface becomes rough and covered with tiny holes, while the lands begin to flatten out, to be 'eaten.'

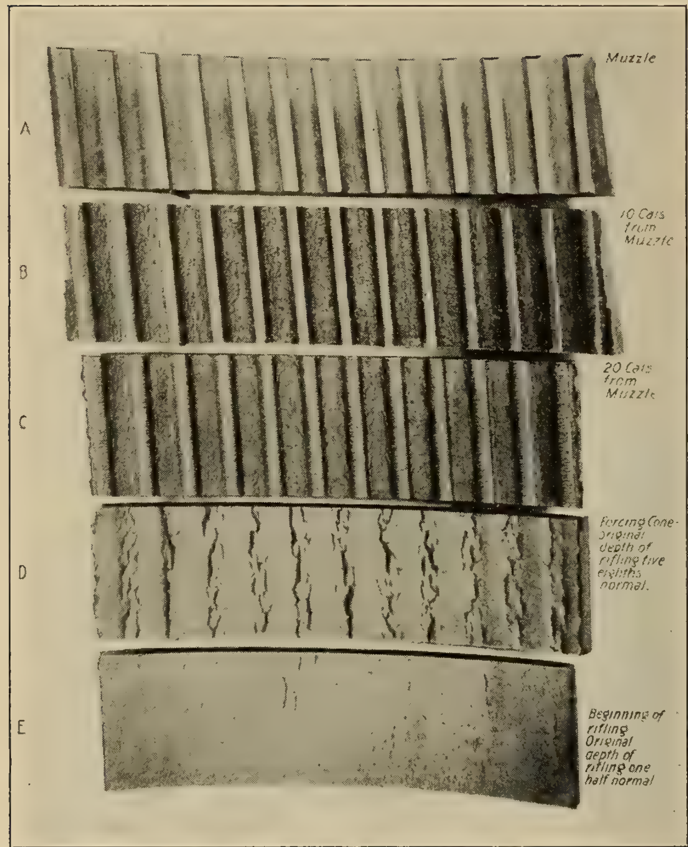
"Some persons compare the action of the gas upon the steel to that of the frosting of glass with sand, but it is not a case of merely mechanical action, for guns are eroded most

rapidly by the powders that develop the greatest heat in burning, those with a base of nitro-glycerine. These, in truth, bring about the fusion of a thin layer on the surface of the bore, and therefore it is more accurate to compare, as some do, the action of the gases on the steel to that of a jet of steam or hot air upon a piece of ice.

"The English metallurgist, Robert Austen, who made experiments on a 12-cm. cannon, which he cut off at 4.25 meters from the mouth, that is to say close to the breech, the cannon being 4.95 meters long, reached the following conclusions:

"(a) As regards the mass of the metal, the action of the explosive was purely and simply mechanical; the particles of metal were profoundly eroded, but no formation of martensite had taken place, which means that the nature of the metal had remained unchanged.

"Martensite is a sort of allotropic condition of the metal,



FIVE SECTIONS FROM A 12-INCH GUN AFTER FIRING 239 ROUNDS
From the Bureau of Ordnance, U. S. Army

which manifests itself more or less when this undergoes tempering, and which destroys itself—meaning that the metal becomes ordinary steel again—following a sufficiently long reheating and a refusion which, as is well known, destroys the temper and brings the metal back to the state of soft steel. A piece of tempered steel contains diffused through its mass a certain quantity of martensite; on reheating it a little to soften it slightly a part of this is destroyed; a longer reheating increases this destruction, which becomes complete when the action of the heat is prolonged sufficiently to make the temper entirely disappear.

"(b) On the parts of the rifling that are in contact with the bands of the projectile during its passage through the tube Austen noted, on the contrary, the presence of a layer of the thickness of 0.127 millimeters in which an alteration manifestly exists, but as to whether this was lamination, puncturing, partial fusion, corrosion, etc., he was not able to pronounce decisively.

"It is well to note that Austen found these effects after only five shots, of which a 120 mm. cannon can fire 600 or 700; so by the time it has become unserviceable the aforesaid layer must have reached the thickness of a centimeter or more."

General Crozier, in the report already quoted, discusses the three theories of erosion, and arrives at a conclusion that differs slightly from Bravetta's, though he does not definitely discard any one of the theories. He writes:

"The surface may be hardened in a manner similar to the hardening of tool steel, *i. e.*, it may be heated by the combustion of the powder to a temperature above the critical temperature, say above 720 deg. C., and the great mass of metal back of this thin layer would suffice to extract the heat so as to cool the steel so rapidly through the critical range that *hardness* of the layer which had reached a temperature above the critical range would result.

"The steel so hardened would be brittle and without any plasticity, and the friction of the rushing projectile might easily produce a series of incipient cracks, which would in time develop in size and extent."

This theory seems to be that adopted by Bravetta. While not rejecting it totally, Crozier is not inclined to accept it, for he writes, "the evidence in favor of this view is not conclusive, and is rather against it than for it. There can be no doubt of the high temperature produced by the combustion of the powder," he continues, "but the velocity of the explosive wave is so great that there would be only a brief interval through which the heat might be communicated to the metal. To raise the metal to the required temperature would require a number of rounds of firing, and the body of the tube being considerably heated, the process would really be a hardening followed by a tempering process giving a fairly soft metal. The surface is, however, glass hard wherever it is found. Definite evidence in regard to the temperature of the metal in various parts of the tube is lacking, and until further evidence is obtained no satisfactory conclusion can be drawn.

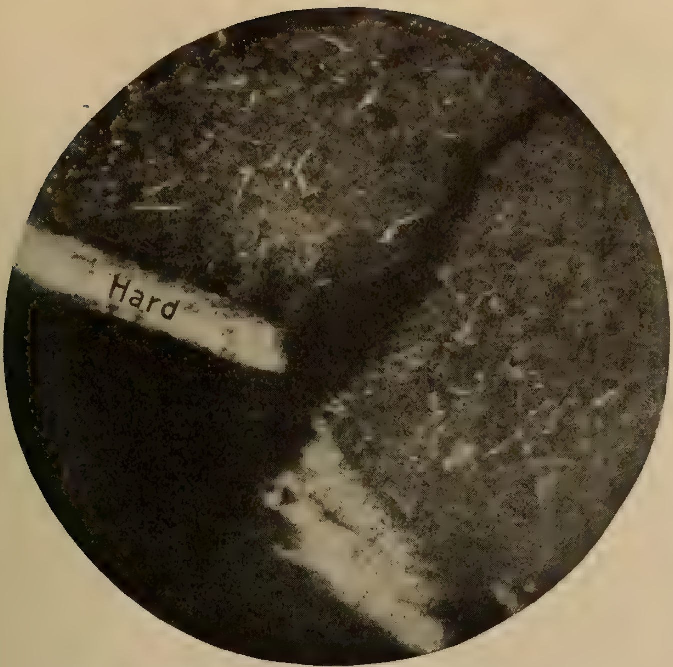
"The second method by which hardness may be produced is by a process similar to wire-drawing and commonly referred to as 'cold work.'. . . . In wire-drawing it becomes necessary frequently to anneal the metal in order to restore the plasticity and thus prevent it from cracking or breaking.

"According to Beilby, a surface skin may be built up by mechanical movement, which gives unmistakable evidence that the surface must have passed through a state in which it must have possessed the perfect mobility of a liquid. This surface possesses distinctive properties which differentiate it from the substance beneath it. Hardening thus results from the formation at all the internal surfaces of slip or shear of mobile layers similar to those produced on the surface by mechanical movement. These layers only retain their mobility for a brief period, and then solidify in a vitreous amorphous state, cementing together all of the surfaces of slip or sheer throughout the mass.

"Such a surface produced by polishing, burnishing, drawing, hammering, or cold work of any kind possesses the property of hardness and brittleness. This layer may be restored again to its natural state by annealing, which destroys the vitreous character of the layer and converts the metal again into its original crystalline, ductile state.

"By the application of this idea to the rifling of a gun we have a simple explanation of the hardening and cracking of the surface. By the passage of the rotating band of the projectile over the rifled surface, the surface of the steel is caused to flow in a mobile layer, and when solidification takes place it is in the vitreous or hard form. After the hard layer has passed a certain critical depth, the mobility is not longer transmitted through it when force is applied by the moving projectile, and the only alternative is for cracks to result from this force.

"The evidence seems almost conclusive that the hard layer and the cracks are produced by this process rather than by the heat alone. The microscopic evidence also favors this view. The hardened layer, etched with alcoholic nitric acid,



TRANSVERSE SECTION OF A CRACK IN THE RIFLING OF A 12-INCH GUN AFTER FIRING 239 ROUNDS, TAKEN AT 325.75 IN. FROM THE MUZZLE. POLISHED AND MAGNIFIED 100 TIMES TO SHOW THE STRUCTURE OF THE STEEL

From the Bureau of Ordnance, U. S. Army

is seen to be distinctly vitreous and not martensitic as would be the case were the layer produced by heating and quenching.

"This theory also accounts for the fact that in Section E, where there is undoubtedly the greatest amount of heat, there are the smallest number of cracks. At the higher temperature there is greater plasticity of the metal, and consequently there is greater opportunity for the cracks to fill up by flow of metal. The friction in this portion of the gun would necessarily be produced by the great rush of gases.

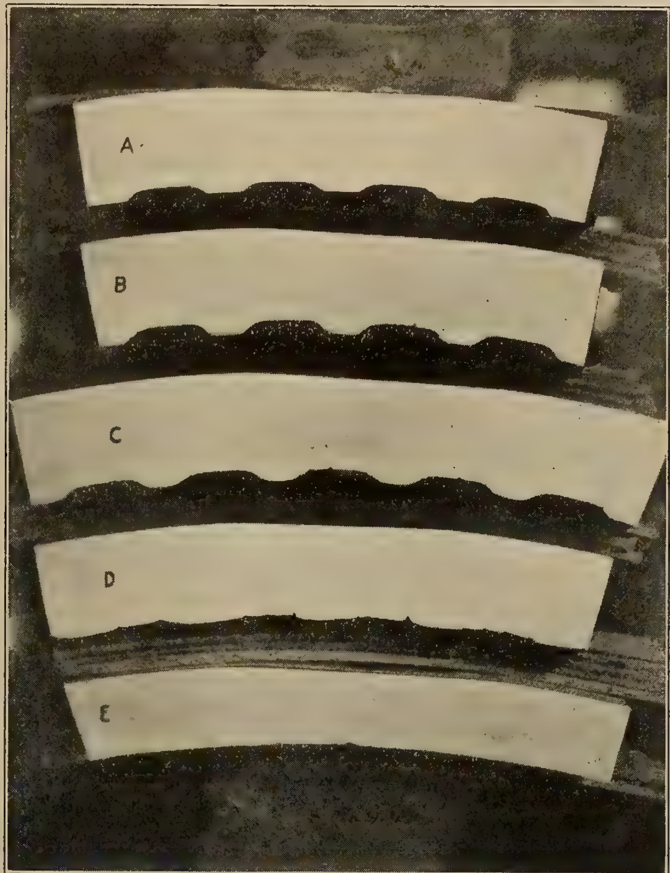
"The third method by which hardness may be produced is by increasing the amount of carbon on the surface of the metal. Tihs might well be caused by a cementation process from the gases produced in the combustion of the powder. This would necessitate a very high percentage of carbon. Inasmuch as the hard layer is so thin and so difficult to do anything with, no direct evidence has been obtained. This method would best account for the fact that the hard layer is thickest in the firing chamber."

Gen. Crozier goes on to describe in detail a series of microscopic tests of various steels that had been subjected to erosion tests, to discuss the changes shown in their structure, and to point out their bearing upon the problem of erosion of big guns. He sums up the evidence in these words:

"It is believed by some that heat cracks are formed because of the formation of a hard surface layer due to heating of a skin of the rifled surface to a temperature above the critical temperature, followed by the sudden cooling of the layer by the large body of metal back of it. If this were true, then such a gun in which heat cracks have developed should show the martensite structure. In the examination of a considerable number of such steels no evidence of martensite has ever been found. In fact, troostite is never found. Therefore it is concluded that the development of heat cracks is due to the pressure of a hard surface produced by cementation of the metal by the products of combustion of the powder and by work put upon the surface by the moving projectile."

It is interesting to calculate how long the active life of a cannon endures, that is, how long it is actually at work. A British 305 naval gun's life, according to a calculation by Sir Robert Hadfield, is only three seconds! This figure is obtained, of course, by multiplying the average number of shots it can fire by the time a shot takes to pass through the tube. A 75 mm. gun, according to Bravetta, lives 25 seconds; a howitzer about a minute, an average mortar five minutes. Therefore the mortars are the Methuselahs of artillery.

"The record for brevity of life," he writes, "probably belongs to the 381 mm. gun with which the Germans in 1915 fired thirty shots on Dunkerque from a distance of 38,000 meters, and to the 'cannonissimo' that bombarded Paris from a distance of 120 kilometers. The projectile of the 381 mm. gun weighed 760 kilograms and had an initial velocity of 940 meters a second, but to hurl it the Germans had to use a charge of 315 kilograms of powder, which tried the metal to the limit of its resistance. This is why the cannon had such a brief life."



FIVE SECTIONS FROM A 12-IN. GUN AFTER FIRING 239 ROUNDS

A, at muzzle; B, 10 calibres from the muzzle; C, 20 calibres from the muzzle; D, forcing cone; E, beginning of rifling. (From the Bureau of Ordnance, U. S. Army.)

When the international artillerists come to the point of comparing their war-time notes with the recent experiments of the metallurgists and analyzing the eroded tubes of the steel veterans of the great conflict, they may possibly find an alloy of chromium, manganese, tungsten, copper, or some hitherto untried metal, that will be proof against the action of the high explosives now in use, and thus lengthen the life of the big guns that cost such enormous sums and are so soon dead.

CANS OF ALUMINUM INSTEAD OF TIN

The *Elektroindustrie* (Zurich) announces the discovery by K. Binggeli, of Bern, of a new aluminum solder which will make it possible to make cans for foodstuffs out of aluminum in place of tin. Rods joined with the solder have been tested by the Swiss National Testing Bureau and show a strength at the joints of 1,500 kg. per sq. cm. The electrical resistance at the joints is very low.

How Men Walk with Artificial Legs*

The Difference Between the Natural Gait and That of the Cripple

By Prof. Dr. R. du Bois-Reymond

HITHERTO judgment has been passed upon artificial legs partly by the general impression they produce with respect to lightness of weight and security of action, and partly by the testimony of cripples. However, observation with the naked eye is extremely ill adapted for the comprehension of the forms of such a movement as walking. For example, we need only recall the general surprise when the true positions of running horses were first shown by means of instantaneous photography. Great numbers of observers had endeavored to indicate the movements made by a galloping horse, but nobody succeeded in doing this until the proper means therefor was discovered in the art of photography. In the same way the gait of a human being has been incorrectly conceived and misrepresented by all observers who failed to make use of instantaneous photography.

For this reason the true nature of the act of walking with artificial legs can likewise be comprehended and measured only by the same means.

Modern photography affords an entire series of different experiments along this line. By far the most perfect of these is the photo-grammetric process for the study of the human gait made use of by the late Prof. Otto Fischer of Leipzig in his famous investigation in regard to this matter. However, this process is entirely too troublesome to be employed in observations upon walking with artificial legs, since in this instance a very large number of different cases must be compared with each other. Furthermore, the high degree of precision obtaind by Fischer is quite unnecessary for our present purpose.

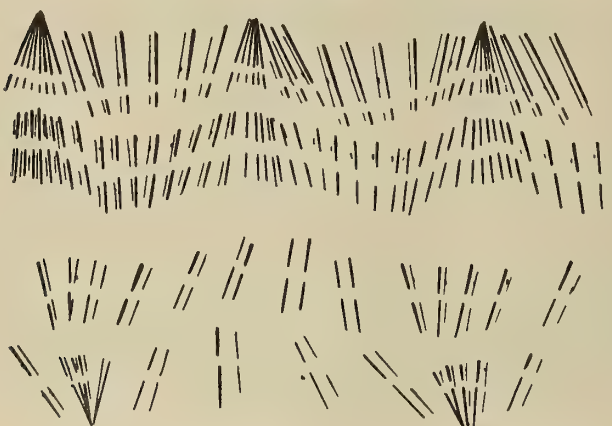


FIG. 1. TWO EXPOSURES ON A SINGLE PLATE

I have obtained the following data consequently by simplifying the Fischer process:

To begin with straight Geissler tubes are attached lengthwise to the legs of a man; through these tubes the induction current produces a flow of pulsating light, while the man moves in front of a camera in a darkened room. Upon the photographic plate only the tubes appear in such positions as they occupy during the flow of light. In this way we obtain, as it were, a series of motion pictures of a skeleton upon one and the same plate (Fig. 1). While it is true that such pictures do not permit very close measurements of the action, yet on the other hand they yield very clear and, in many respects, entirely trustworthy views of the processes of motion, from which many data can be obtained which it would be impossible to get by mere observation with the naked eye.

In the testing of artificial legs this process is of especial advantage since it permits us by making use of two cameras to show the movement of both legs at the same time (Fig. 2); we can then be certain that under the same conditions, *i. e.* with the same stride, the artificial leg and the sound leg have made the actual movement shown upon the plates.

Through the kindness of the Emil Busch firm in Rathenow two similar lenses of exceptionally high power were placed at my disposal for the purpose of taking double photographs of the walk of a man having an artificial leg. These experiments were conducted in the Physiological Institute of the University of Berlin. In order to be able to examine at the same time the large numbers of patients who had undergone amputation in the Reserve Hospital at G., I also applied to the firm of E. Zeiss in Jena, which likewise kindly lent me a pair of very beautiful lenses.

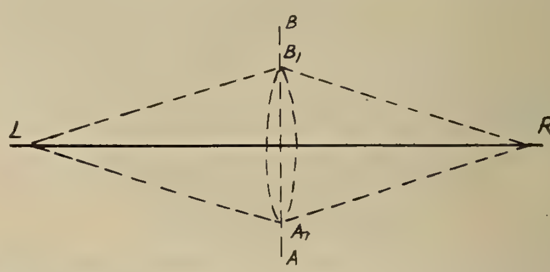


FIG. 2. TWO CAMERAS L, R, SET 5 M. FROM THE PATH A-B FOLLOWED BY THE PATIENT

In order to understand the movement pictures of the walk with an artificial leg it was necessary, in the first place, to obtain a picture of the normal walk for purposes of comparison. It might be supposed that the Fischer view of the normal walk as shown in Fig. 3 would suffice for this purpose. However, it is not precisely adapted to our present object, since it represents a vigorous "walking" stride (length of stride about 0.8 m. or 2 6/10 feet, and rapidity 1.67 m./sk) whereas the wearer of an artificial leg takes much shorter and slower steps. To begin with, therefore, we must determine the form of the normal motions during a slow walk (Figs. 4 to 6), in order to compare with these the movements of the cripple provided with an artificial leg. Nothing further need be said here concerning this except to mention one basic observation, namely, that the upward and downward changes of place made by the center of gravity of the entire body are much smaller in extent during a slow walk than during a rapid walk.

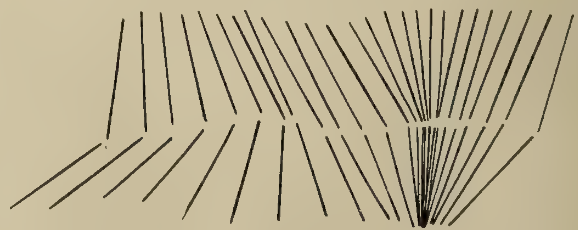


FIG. 3. NORMAL FAST WALK ACCORDING TO FISCHER

Thus far my observations have been confined almost exclusively to the movements of the upper and lower leg bones, from which, however, it is possible to comprehend the variations of place in a vertical plane of the buttocks. If we now compare the views of the walk of a man with an artificial leg with those of a normal walk equally slow, we perceive that

*Translated for the SCIENTIFIC AMERICAN MONTHLY from the *Zeitschrift des Vereines Deutscher Ingenieure* (Berlin), Aug. 4, 1917.

in all cases without exception the sound leg of the wearer of an artificial leg also deviates in its gait from the normal movement of walking (left half of Fig. 7 and Fig. 11).

It must be remembered also that a comparison between the movements of the artificial leg and those of the sound leg is by no means the same as the comparison between the gait of the artificial leg wearer and the gait of a normal man. As a matter of fact it must be differentiated in three respects: 1. The normal movement of walking in which both legs of a normal man move in the same manner; 2, the movement of the artificial leg; 3, the movement of the sound leg during the walk of a cripple wearing an artificial leg. In order, therefore, to comprehend and pass judgment upon the gait of arti-

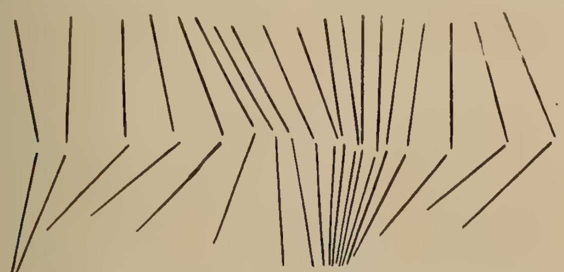


FIG. 4. NORMAL SLOW WALK (48.5M./MIN.)

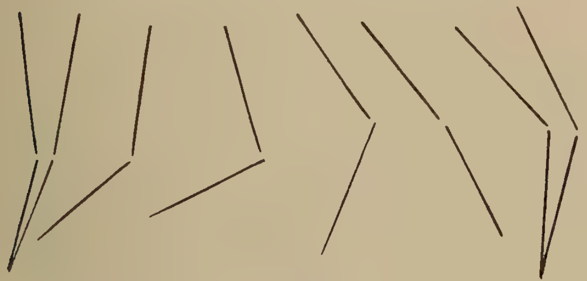


FIG. 5. NORMAL FAST WALK (141.6 M./MIN.)

FIG. 6. SAME AS IN FIG. 4 DIVIDED INTO SAME NUMBER OF POSITIONS AS IN FIG. 5

ficial legs, it is necessary to compare views representing the sound side and the crippled side of the wearer with views of the normal gait, instead of merely comparing the sound side with the crippled side of the same subject.

I. *Comparison of the Views of the Cripple Side (Furnished With an Artificial Leg) With the Normal Movements of Walking.*

1. During the movement of swinging forward the artificial lower leg hangs back much less than the normal leg. In a slow normal walk the knee is accustomed to bend from 140° to 130° while the movement of the artificial leg is 20° to 30° less. Artificial legs of different construction vary perceptibly in this respect, as can be seen in Figs. 8, 11, etc.

2. While the artificial leg is resting upon the ground and supporting the body it remains fully extended, as shown in Fig. 8, etc. The knee of a normal leg on the contrary remains slightly bent during the act of support, as shown in Fig. 4.

These two characteristics are always present in the action of artificial legs. They can be readily traced to a mechanical cause. In the walk of a normal person (see Fig. 4), when the point of the foot has been lifted from the floor, the lower leg is drawn up for a moment and then swings freely, while the upper leg is drawn up for a moment and then swings while the upper leg is brought forward. Through the movement of the upper leg the upper end of the lower leg is carried forward with the former, while the lower end at first lags behind, which increases the flexion of the knee. When the upper leg comes forward again the lower leg follows it with increasing rapidity so that the flexion of the knee is decreased once more. Shortly before the foot is set down the forward movement of the upper leg either ceases or is retarded and since the under leg swings further freely the leg at once assumes the extended position.

In the case of an artificial leg it is obvious that the lower leg is not drawn up at the beginning of the swing, hence the flexion of the knee is produced exclusively by the lagging behind of the lower leg and is, therefore, weaker and slower. It must be remembered furthermore, that the common center of gravity for the lower leg and the foot in a natural leg is found at about the middle of the lower leg, whereas it is generally lower down in an artificial leg fitted with a boot.

The cause of the second difference between the motion of the

FIG. 7. SOUND AND ARTIFICIAL LEG AFTER FIRST DAY

FIG. 8. SAME AS FIG. 7 AFTER FOUR WEEKS' USE

artificial leg and that of the normal leg, namely, that the knee remains extended while the leg is supporting the body, consists merely in the fact that the artificial leg lacks the muscular tension necessary to enable it to act as a support while in a slightly flexed position.

3. A third difference between the normal gait and that of the artificial leg is that the hip upon the side of the latter is lifted considerably higher during the swing of the artificial leg than is the case in normal walking, as can be seen in Figs. 8 to 11, etc.

Since at the beginning of the swing the artificial leg is incapable of being moved either at the knee or the ankle, like a natural leg, through musuclar activity, and hence swings with a slighter flexion, there is a tendency shown by the point of the foot to drag. This tendency can be avoided by lifting the hip higher. But the hip must also be lifted when the body is turned towards the other side as happens in normal walking. Furthermore, the wearer of an artificial leg lacks the ability to "push off" properly from the ground as is done at any rate in many kinds of walking, by a person with a normal leg. It is probable that the cripple compensates for this defect by a fling of the buttocks. In order to determine whether this supposition is correct I made views of the forward and backward movement of the buttocks of men equipped with artificial legs; these views showed first that in this point also the natural gait differs from that of the artificial leg, since in the latter case the inclination of the buttocks is considerably more marked. However, these variations still remain to be studied in more detail.

In any case it is evident that various conditions operate together in the matter of the increased lifting of the hip.

In some cases, especially in beginners, the hip and with it the whole body is quite obviously lifted powerfully upwards and inclined towards the side of the supporting foot in order to fling the artificial leg forward with the required impetus. This very unskilful movement is abandoned as the patient becomes increasingly accustomed to the artificial leg, but in most cases the marked lifting of the hip continues permanently (see Figs. 7 and 8).

The curve described by the hip presents a different outline in patients of different degrees of skill in the use of the artificial member. In some cases the apex is quickly reached (see Fig. 9) and the largest part of the curve begins at the concavity, while in other cases the apex of the curved line lies quite near the end (see Fig. 11) so that there is a steep decline at the end. Presumably the same object is here attained in two different ways. Furthermore, there are some cases in which the curved line or "wave" rises and falls quite regularly (see Fig. 8, etc.).

In connection with the excessive lifting of the hip, especially in those cases in which the apex of the curve occurs near the end of the swing, there is frequently found a fourth deviation from the normal in the motion of the artificial leg, consisting in the fact that before the setting down of the foot the leg is swung too far forward and then drawn back again. In the normal gait forward movements in space are made exclusively. It is true that there is a relative backward movement but this backward movement is never absolute. Each such movement indicates likewise unnecessary double work. The unskilled wearer of an artificial leg, on the other hand, not infrequently makes backward movements either with the artificial leg or with the sound leg. These movements are generally quite plainly indicated in the accompanying illustrations by the circumtsance of two adjacent lines crossing each other (Figs. 7, 16, etc.). Such a crossing of the lines takes place when the upper leg before the end of the swing of the leg is brought back with more force than in the normal gait, in order to fling the lower leg forward. Crossings of the lines appear in the views of the lower leg when before the setting down of the foot the leg is thrown too far forward and must be drawn backward and down in order to touch the ground.

II. *Comparison of the Movement of the Sound Side of a Cripple With the Gait of a Normal Man.*

The only deviation from the normal which is visible in all the views of the movement of the sound side of a cripple wearing an artificial leg consists in the increased lifting of the hip during the swing. Practically the same thing can be said of this as in the case of the lifting of the hip on the side furnished with the artificial leg. (Fig. 12).

FIG. 9. ARTIFICIAL LEG, LIFTING OF HIP

FIG. 12. SOUND LEG OF SAME AS SHOWN IN FIG. 11

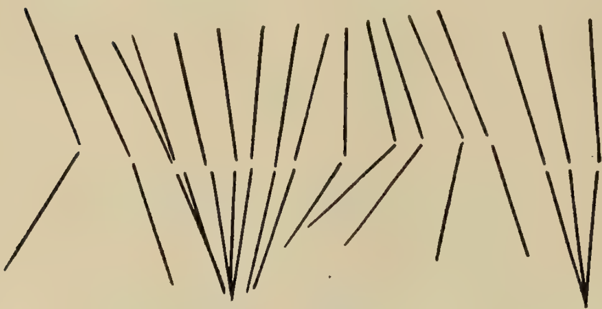


FIG. 10. ARTIFICIAL LEG, IRREGULAR LIFTING OF HIP

FIG. 13. SPECIMEN OF SKILLED USE OF ARTIFICIAL LEG

FIG. 11. APEX OF LIFT NEAR END OF CURVE

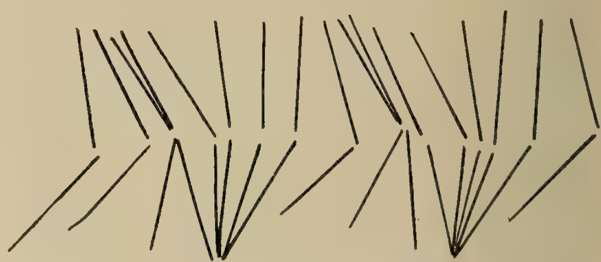


FIG. 14. SKILLED USE OF ARTIFICIAL LEG

Besides this we also observe in some cases the crossed lines upon the sound side, which indicate a backward movement of the leg in space (Fig. 21). The upper leg especially is frequently moved forward too much at the end of the swing and must consequently be drawn back again. Especial attention may be called to the fact that a practised wearer of an artificial leg tried three different artificial legs of various manufacture in succession and in each case made the same mistake with the sound leg. (Figs. 13 to 20).

This observation is of peculiar importance since it proves that such a mistake upon the part of the wearer of an artificial leg may have a physiological cause instead of a merely mechanical one. We can obviously explain in this way the fact that the patient in his efforts to control the artificial leg with which he is unfamiliar makes movements of excessive extent with his stump. Because of the mutual relation which the nerve centers governing the motion of the legs bear to each other, this effort involuntarily occasions excessive action of

the sound leg. This teaches us that a patient who is learning to make use of an artificial limb must not only learn to make the correct motion with the stump, but that the sound leg must be trained also to prevent it from making all sorts of unsuitable movements through its nervous coördination with the stomach (Fig. 21).

While at first glance the deviations from the normal described above may not seem very essential, careful consideration shows that they exert quite an important influence upon the degree of effort required by the act of walking. According to Fischer in a normal fast walk the hip is raised and lowered about 4 cm. at each stride and the center of gravity of the whole rises and falls a like distance. According to Katzenstein and Zuntz the total work done in walking by a man weighing 55.5 kg. (about 122 pounds) is 315.4 mkg. Counting eighty steps to the minute the lifting of the center of gravity alone would equal 80 x 0.04 x 55.5 = 177.6 mkg., *i. e.* something more than half of the total amount of work done. When, therefore, the lifting of the hip and with it the lifting of the center of gravity is increased to double the normal, which not seldom occurs in the wearing of an artificial leg, the work done by such lifting amounts to 355.2 mkg. per minute; thus we see that such lifting movements alone require a greater expenditure of energy than the entire action in a normal walk. Accordingly, when all other conditions remain the same the increase of the lifting movement increases the work done in normal walking by 164 vH. These facts show the necessity of making use, in the examination of artificial legs, of a process that will reveal even very slight differences in the movements.

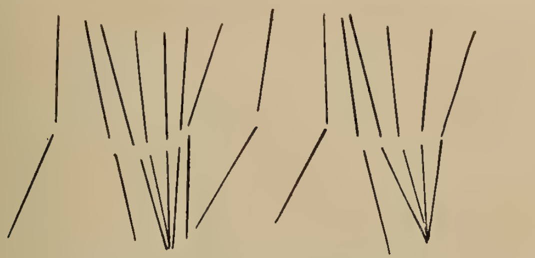
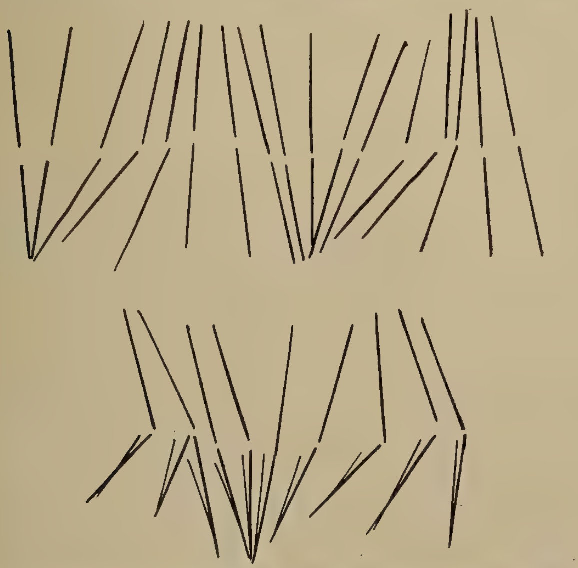
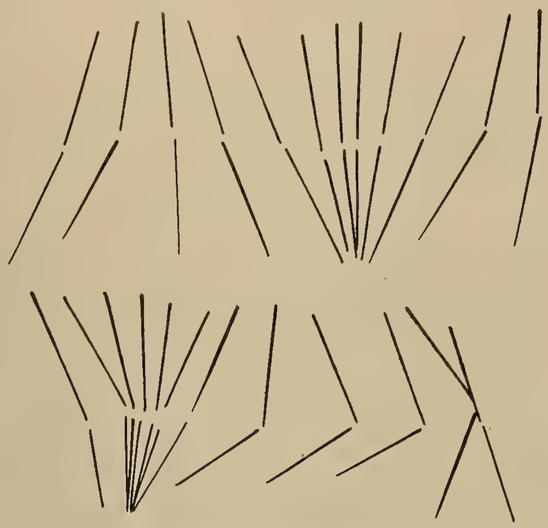


FIG. 15. SPECIMEN WITH DIFFERENT TYPE OF LEG

FIG. 16. SPECIMEN WITH DIFFERENT TYPE OF LEG



FIGS. 17 AND 18. NOTE THAT THE SOUND LEG MAKES A BACKWARD MOVEMENT



FIGS. 19 AND 20. SAME ARTIFICIAL LEG AS IN FIGS. 13 AND 14

FIG. 21. SOUND SIDE, STANDING STILL DURING ACT OF SUPPORTING THE BODY

SUMMARY.

In the testing of artificial legs it is not only useful but almost indispensable to record and study the movements of walking by means of instantaneous photography. By far the most exact process devised for this purpose is that of Otto Fischer. Since, however, this process is much too troublesome to be applied in the comparison of a very large number of cases, we must content ourselves with the somewhat lesser degree of precision which is obtained by combining the older process of Marey with that of Fischer, as follows: The longitudinal axis of the members is made recognizable by attaching to the members a Geissler tube through which a succession of induction flashes is sent at brief and equal intervals of time. The movements are made in a darkened room with a continuously acting camera, so that the tubes make an impression upon the plate, so to speak, as of the movements of a skeleton in the same series of positions which they had at each passing of the flash. The resulting views show plainly that the movement of the artificial leg always differs from that of a normal leg in certain particulars, and also that the movement of the sound leg of a cripple likewise differs from the normal gait.

That these deviations though slight are not unimportant, is shown by a simple arithmetical calculation proving that merely through the increased rise and fall of the body at each step taken the amount of work done in walking with an artificial leg is increased by more than fifty vH. as compared to the normal.

This calculation shows the necessity of examining the action of artificial legs by means of a process which will show the slighter differences as well as the greater ones in the form of the movement.

A Prime Cause of Inefficiency in Industrial Organizations*

Determining the Best Way to Do Work

By Frank B. Gilbreth, Mem. A. S. M. E. and L. M. Gilbreth, Ph.D.

ALL trades, and particularly those connected with this Association are unnecessarily inefficient to-day. You know it; we know it. What are the causes?

There are demands for changes in wages, for better hours, and for increased production. Are these demands just or unjust? In any case the demands must be answered in some way.

The answer lies in the increase of skill. In our paper presented to this Association last year, we showed you how skill could be discovered, measured, standardized, and transferred, and we brought as illustrations many films that showed in great detail the various stages of the process.

The problem facing us as a nation, and you as a group of metal working men, last year was largely a problem of maximum production. Some phases of the labor problem were not so pressing at that time, because of patriotism inspired by war necessities. To-day the labor problem stands in the foreground of attention. We are making you the same answer to-day—increase of skill, and that alone can answer the present demands upon you.

It can scarcely be necessary to demonstrate to you that lack of skill is the prime cause for inefficiency in your particular work, as it is in all kinds of work—in this country, and in fact, all countries. You may not, however, as yet realize that lack of proper teaching is the underlying cause of this lack of skill.

Efficiency in teaching consists primarily of three things: *first, determining the best way to do work;* second, *conveying in least time, information of how to do work in the one best way;* third, *presenting information so that it can be longest remembered.*

The greatest obstacle to overcome in increasing skill of a group of workers is that they have been taught the average methods by the average teacher. We are all ready to admit this. We are not all, however, as ready to admit that the average teacher has had no opportunity to learn the best method, and is not equipped with modern devices for conveying information. The fault lies ultimately, then, with the industry itself, in not having determined, captured, and recorded the one best way, or at least the one best way extant, and put it at the disposal of the teachers.

The first step in this process must consist of recording the best present practice. This is, however, not so simple a process as it might seem to be. The records must include many things. Our researches have emphasized several laws, and an idea of these is essential if the existing information on this subject is to be secured, and this *must* be secured before the one best way can be deduced.

For example, it is a law in motion study efficiency that no two workers are found to use precisely the same motions, even in the same kind of work. This necessitates observing and recording the activities of *several*, and oftentimes of *many* workers performing the identical operation. If you are observant, you have noted this in your own work.

It is a law of Motion Study efficiency that every demonstrator has been found to have at least three sets of motions, and that he *does not* and *can not* use the same motions when he is working with the automaticity of skill at the usual speed that he uses when he demonstrates his methods at the slower, "demonstration-speed." This necessitates making records of usual and demonstration methods, and also at reduced and increased speeds, in order to note and record the variations.

It is a law of Motion Study efficiency that the synthesis of the best portions of the methods of two or more of the best workers will be found to present a method that is more efficient than the best method of any one worker. In the film shown here you will note that the methods of the workers vary exceedingly, and that some of the so-called "best workers" use some very inefficient methods, such as not using the left hand properly.

It is a law of Motion Study efficiency that the worker with the best record of outputs is not always found to be the best for demonstrating personally the one best way to the learner. His large outputs may be the result of his superior strenuosity and in spite of a poor method. Furthermore, knowledge of pedagogy does not necessarily accompany knowledge of one's job. It is necessary, therefore, to demonstrate the various methods to the best available teacher, and to record his method of demonstrating the activities of a learner.

The best way is then determined by making records of the usual and demonstration methods of the best workers available, by analyzing them, and combining the best elements of the methods into the one best method, and by having this demonstrated by the best available teacher.

Having then secured this record, the actual teaching process consists of using the resulting film as a teacher, supplemented by the usual available teaching methods, oral, written, or whatever they may be. This record of the one best way having once been obtained is available forever. It teaches all new-comers the best that has been. It will present the information in the best way that the best teacher has ever presented it. This in no way resembles the so-called "commercial moving pictures" that you have so often seen. This information, "available forever," is also *instantly* available. It can easily be brought to the foremen's meeting. It can be duplicated easily and cheaply and put at the disposal of manual training schools and corporation schools.

Compare this with the way you are now teaching trades. In 1910 we said in Motion Study: "The present apprenticeship system is pitiful and criminal from the apprentice's standpoint, ridiculous from a modern system standpoint, and there is no word that describes its wastefulness from an economic standpoint." The great Amar has said the same obtains to-day in his country. Your present methods of teaching must be overhauled and research laboratories inaugurated.

Every day that passes serves to emphasize more strongly the correctness of these methods which are based upon teaching through the eye. Written instructions, charts, drawings, lantern slides, stereographs, and moving pictures—these all serve as teaching devices for visualizing the process. Micromotion films have proved themselves particularly adapted to an efficient learning process. The activities to be studied may be repeated, at will, as often as may be desired, according to the needs of the learner. An activity may be analyzed into its component parts, and even into the elements of the motion by taking a large number of pictures per second and then slowing down the process when the film is exhibited at the usual rate of speed. Again, the activities may be analyzed by means of mechanical and other drawings made especially to illustrate one point at a time, with all extraneous subjects omitted. An activity may be summarized, by taking the pictures at much slower rate of speed than is usual, and then exhibiting them at the usual speed.

"*Attention*" may be secured and interest held by *exaggeration* as to scale and by means of the "surprise" by sudden changes of scale and also by the use of the "close-up." *Emphasis* may be secured by means of moving cartoons to illustrate a particular point. The *sequence* of operations may be made impressive by running certain portions and in certain cases, all

*Presented at the Convention of the American Foundrymen's Association, Philadelphia, Pa.

captions inserted in the picture, which allows of including "reasons" with "directions."

"*Continuity of thought* can be obtained by associating each point or picture to be remembered with the point that comes immediately before it and immediately follows it through moving mechanical drawings or cartoons.

Likenesses to other activities can be demonstrated by including bits of film showing similar activities in other lines of work. These are only a few of the benefits of the film as a teaching device, pointed out here that you may note them as exemplified in the film itself. Note especially the possibilities for associating the various steps of an efficient learning process, because upon a proper association depend quick learning, easy remembrance, and efficient activity. The memory experts base their systems upon such association. They, however, have been obliged to be content with "mental pictures," made by a "mental process," without the actual pictures having been previously recorded through the eye, while we have here a device which makes such recording through the eye possible and simple, and the resulting remembered image vividly and easily recalled.

It may seem a long cry to an increased production of cores from a motion picture film of core-making—but some day you must come to realize that, through the discovery and adoption of "the one best way to do work," and through that alone can come the increased production, the increased wages, and the increased health and happiness of workers that are essential. In the meantime, we can do nothing but come before you year after year to present the methods of recording and teaching this best way, and to advocate such recording and teaching as a remedy for the evils which you acknowledge beset you.

As for the practicability of the method, in order to cooperate in work for the blinded, to make available to a group of men and women who desire factory work a new activity, and to relieve sighted workers of work which might be done by the blinded, thus leaving the sighted free for work requiring eyes, we have, during the past year, through the co-operation of Mr. A. B. Segur and the others of the Red Cross Institute of the Blind, made records of one of your own activities, namely, core-making. As a result of these records, and the deduction of the one best way for making cores, Professor Wallace, Director of the Red Cross Institute of the Blind, at Evergreen, Md., has just sent to us an announcement of their courses, including a course in core-making. We are to-day presenting some of these films to you. They will show you that this process applied to one small division of the work of an industry, will standardize the activity involved, will make possible its division into parts requiring different capabilities, will add a new group of available workers, will supply a new element of interest, will result in increased production, will make possible the pay of higher wages, will eliminate unnecessary fatigue, will exemplify efficient motions, and will do away with a prime cause of inefficiency by supplying an adequate means of discovering, standardizing, and transferring skill.

The method recommended by this paper has been criticized by some who have based their judgments upon their experience limited to the so-called commercial moving pictures.

It has sometimes been thought that the expense of this method is so great that it could be afforded only by groups of employers or by an association. But this is not true.

It is not expected that this method is ever to be carried so far as to approach a diminishing return, and when it is realized that the difference between usual and customary output and the outputs resulting from this method of research and teaching is usually more than three to one and sometimes five to one, the importance of recording the one best method of doing work and teaching it can be realized.

Men of the metal industries, you must recognize that this is a crucial moment in the industrial development of this country, that the time for petty disputes, for trade secrets, for "minor wastes," for retrogression or lack of progress is past. You have shown your interest in this subject by inviting us to present to you for the second time films showing this particular method of attack. You have welcomed illustrations from your own particular field, as supplementing those from the other fields in which you were interested. It remains now for you, yourselves, to attack your own industry; to eliminate the inefficiencies there existing; and if you will, to serve as a model to other industries by co-operation both in research, in interdissemination, and in installation. Such co-operation is becoming more general everywhere. It is indicated in the new book by the Bloomfields on Employment Management. It is shown in Mr. Gantt's new book on "Organizing for Work," where he emphasizes the importance of visualization by means of charts. Any method of co-operation is commendable. The need for this particular type of co-operation at this time is that the "during the war" desires and methods of attaining efficiency for patriotic reasons are lapsing with the much-desired days of peace. In your industry, you evolved magnificent results and efficient methods at the call of your country. It is your duty now to see that these do not now lapse and perhaps disappear through the pressure of other problems. Maintain, then, your before-and-during-the-war co-operation by combining to record your best methods, and to put these together with the one best way of research at the disposal of your entire industry. It is the greatest offering that you can contribute towards meeting the economic needs of to-day.

RELATION BETWEEN WEIGHT AND SEX IN EGGS.

THE claim is made in a paper recently read before the French Academy of Sciences that the weight of eggs bears a definite relation to the sex, provided the breed be homogeneous and pure and the hens laying the eggs of approximately the same age and size. This theory is advanced by M. Leinhart, whose attention was attracted to the matter by the obervation that in all breeds of fowls the cock is always larger and heavier than the pullet of the same age. By numerous experiments he found that the variation in weight for the breeds examined was between 500 grams and 1 kilogram or more in the adult fowl. Furthermore this difference appears even in young chicks, varying from 18 to 27 gr. in those five days old. The idea naturally suggested itself that the same difference might exist in the egg. In the spring of 1918 M. Leinhart selected sixty eggs chosen because of their size from a lot of 350 all laid by Leghorn hens. These 60 eggs varied between 59 gr. and 70 gr. in weight. Repeated experiments previously had shown that the average weight of Leghorn eggs is 62 gr., the minimum weight being 54 gr. and the maximum weight 70 gr. Eggs weighing less than 58 gr. or more than 66 gr. are rare, however. Among the eggs chosen 7 weighed slightly less than the average while the others exceeded it. The 60 eggs were hatched in an incubator and yielded 48 chicks, comprising 37 males and 11 females, *i.e.*, a proportion of 77 per cent. of males. This result convinced the experimenter that the sex of fowls can be determined in the egg, a fact whose knowledge would naturally be of great advantage to breeders. Mr. Leinhart expects to continue his experiments but warns breeders or scientists who would do likewise that the fowls experimented with must be pure bred, that the hens be of the same age and that the eggs be gathered when the laying period is at its maximum. This is important since year old pullets lay eggs which are considerably smaller and less in weight than the normal average of the breed, while during the course of a year the eggs of the same hen, even when fully adult, are considerably smaller at the beginning and at the end of the egg-laying period than when it is at its height. Hybrids cannot be employed for the experiment, since here the Mendelian law comes into play and the eggs produced vary greatly in size correspondingly.—M. Tevis.

A 75 HORSE-POWER TRACTOR HAULING 13,400 FEET OF GREEN YELLOW-PINE LOGS

Logging with Belt Tread Tractors*

The Use of "Caterpillar" Trailers

By C. D. Metcalf

DURING the war one of the much criticized lumber corporations promoted one innovation in logging methods which is destined to have a far-reaching effect on the logging industry. With the sanction of the Production Board, this company purchased two 45 horse-power belt-tread tractors with the intention of using the engines for hauling logs on trailers over newly made roads. It was soon discovered that the tractors could be profitably employed for skidding as well as for hauling logs on wagons. The tractors were put into commission for skidding and were operated with much success.

However, it remained for T. P. Jones, who is accredited with having introduced many novel ideas in logging engineering, to seize the real possibilities of the belt-tread tractor for skidding. Working with the manufacturers of the tractors, Mr. Jones has perfected a belt-tread tractor and trailer system, under which logs may be put in for approximately one-half the expense of working teams, as commonly practiced in Idaho.

In lieu of the round wheel trailers, the company is now using for skidding, the so-called "Caterpillar Bummer." This consists of a truck with a single bunk, (or sometimes two bunks) mounted on tracks built up much on the style of the tractor tracks. The bummer construction is shorter than the tractor, the weight of the load being supported by three truck wheels on either side.

The bummer and its load are pulled by a 45 horse-power tractor of the model made famous during the war for artillery hauling purposes. It has a very long and flexible track, which conforms to, and gives traction on uneven road surfaces. There is no front steering wheel. The steering is accomplished by means of two clutches, each of which controls independently its side of the belt tread. No equalizing or differential gearing is used. The entire power of the tractor motor may be employed on either track when occasion requires. Each track has independent brakes. Thus the operator may apply the brake on one truck, and by engaging the friction clutch on the opposite side can turn the tractor in its own length. The motor is of the four cylinder, slow speed, heavy duty type with flyball throttling governor. The traveling speeds (1½ to 4 miles per hour) are obtained by gear changes. This engine will pull its load over logging roads too soft and rough to be easily negotiated with teams or motor trucks. The great ground bearing surface of tractor and bummer prevent the outfit from miring down.

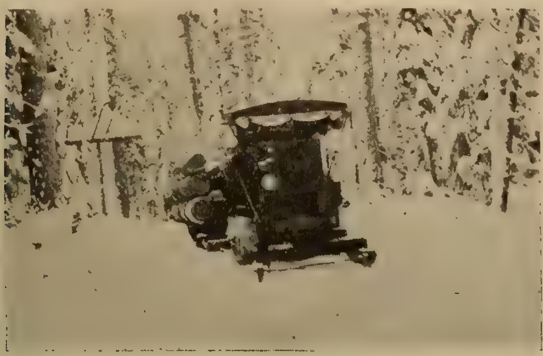
The first outfit purchased was used in "selective" logging operations, but later, as the utility of the system was proved, the company installed a second outfit, and is now putting in the major part of its logs with this equipment. The tractor and bummer are used regularly for skidding on hauls up to a mile. Briefly, the plan is to cut a road from the railroad through the timber for the desired distance. The trees are felled across the road and for a short distance on either side. The logs are trimmed and several of them (depending upon the size) are raised on one end until supported by the bummer; the other ends skid on the ground. Twenty-five hundred to 3,000 feet is the usual bummer load.

The two outfits have been operated at Bovill, Idaho, for a year, having been put into service in the fall of 1918. They proved highly efficient in the winter for skidding operations on snow and ice roads.

TEN-TON ARTILLERY TRACTOR HAULING 6,000 FEET OF WESTERN PINE ON AN EIGHT-WHEEL TRAILER

*From the *West Coast Lumberman.*

In the skidding operations with 32-foot white pine, two outfits are averaging 40,000 feet per day on one-half to three-quarter mile hauls. Nine men will average 20,000 feet per day, or 2,220 feet per man per day. This is for skidding logs in three lengths within a half-mile radius.



TRACTOR OPERATING WITH SLED TRAILERS IN THE SNOW

The belt tread tractor with trailers may be profitably used at some camps in lieu of a railroad. The expense of the equipment is trifling as compared with the cost of a railroad, and when the job is finished the outfit can be quickly moved to another haul. Wherever a spur of railroad is thrown in it has to stay when you leave, for you don't take up ties and you cannot remove your road bed. This engine will build the road over which it is later to travel. It is the best road builder in existence.

It will pull stumps up to 18 inches in diameter in direct pull without the use of tackle, or it will pull 20 feet of engine graders or train of dirt wagons. It is a complete road building power plant provided with its own steel road bed. Where the proposition is strictly one of hauling over a considerable distance, say from two to five miles, it is essential to load as heavily as possible and to keep the engine constantly on the road. On these long hauls it must be borne in mind that the tractor outfit is really doing the work of a steam railroad, and the results will depend largely on the condition of the road bed.

A 45-HORSE-POWER BELT-TREAD TRACTOR SKIDDING WITH A "GO-DEVIL"

The better the road is kept up the bigger the loads and the smaller the expense. A good practice is to attach to the rear trailer of a "Caterpillar" logging train a "V" drag which follows the wagons and smooths out the rough spots in the road. An occasional trip with this drag will keep the road in fine condition. Where the roads are very dusty a sprinkler wagon may be made a part of the equipment.

On these long hauls where round wheel trailers are used, the tires should be very wide; 10, 12 or even 16-inch tires are none too wide. Some loggers recommend the 3-wheel trucks commonly used in Louisiana. If the roads are very soft or sandy the belt tread bummer is better than any of the wheel trailers. These trailers will carry their loads wherever a belt tread tractor will go. The wagons should be of sufficient capacity to handle 3,500 feet of green yellow pine logs. Three wagons with 3,500 feet each, or 10,500 feet makes a good average load for a 75 horsepower tractor.

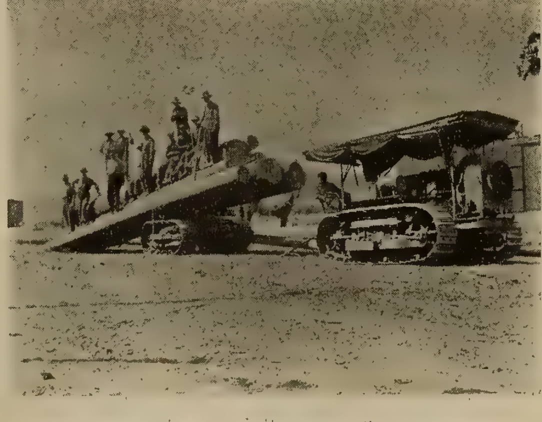
This large tractor is primarily a "roader." It is almost twice as big as the 45 horsepower tractor previously described, but embodies the same features of construction, except that it is equipped with a front wheel. The front wheel is necessary to give the big tractor balance. On the 45 horsepower tractor the front wheel is dispensed with; on this account the smaller model is to be preferred as a "yarder."

B. F. Pierce, manager of a lumber company at Colville, Washington, describes his operations with 75 horsepower tractor hauling equipment as follows:

"The tractor moves at the rate of 2¼ miles per hour under load, drawing three 3-wheel trailers, which weigh 7,800 pounds each and are equipped with 16-inch tires. The usual load of logs transported is 11,000 feet. On a three-mile haul we make three round trips daily, bringing in an average of 30,000 to 36,000 feet per day. Estimating about 8 pounds per foot as the weight of green western pine logs the combined weight of the load, including trailers, totals 111,400 pounds. It will be remembered that this tractor loads directly in the woods under any sort of condition. It requires only two men to operate the outfit. We figure that the tractor displaces ten teams. The average price now being paid for a team and driver is $9.00 per day. This is our second season with the tractor and we are pleased with its performance. The old horse team is a thing of the past with us. Using distillate at 17 cents per gallon, and allowing depreciation sufficient to make the life of the outfit five years and operating with two men we figure the cost of a tractor outfit at $30.00 per day. Thirty dollars would not pay the expense of the teamsters to drive the horses the tractor replaces."

The company uses nine trailers; three are kept constantly on the road; three at one end of the haul are being loaded, while three at the other end are being unloaded. Up to date, and after two season's use, they have practically no expense for repairs and no delays, and they state that the tractors are as good as new.

For winter work in Eastern Washington, Idaho and Montana, heavy logging sleds take the place of the trailers. Under favorable conditions it is possible for a belt tread tractor to haul 20,000 feet or more per trip loaded on sleds. The tractor tracks gain easy footing on snow roads, and where necessary, as on



"BUMMER" USED AS TRAILER IN CONNECTION WITH THE BELT-TREAD TRACTOR

ice roads, the tracks may be fittted with angle steel grousers bolted to the shoes. This gives the engine a firm bite on any road bed.

For loading operations the tractor may be equipped with a spool or windlass attachment. This consists of a cast iron drum which takes the place of the stationary pulley attachment on the smaller model, or is placed on the rear countershaft of the larger tractor. The engine can thus be made to do the work of another team and driver.

Operators are plentiful. Thousands of young men who enlisted in the "Tanks" have returned from France where they gained much practical experience in the handling of tractors. Many of these men had tractor experience before they entered the service and were selected for the tanks on this account. Now they can qualify as experienced tractor operators. These men have been used to hard knocks and accustomed to discipline. Furthermore, and most important, they are not of the Bolshevist element. The average tractor logging outfit is doing the work of ten teams with ten drivers; and many plants will welcome the system as a means of relief from the high cost of horse feed and the I. W. W.

The belt tread tractor with its powerful motor and crawling ability can be put almost anywhere. On the west front the engines crawled in and out of shell holes and pulled their loads over battle-torn roads and made good. The tractor can do all these things in the woods.

At every camp there is more or less extremely rough yarding to be done. Here the tractor is called upon to repeat its war-time performances. The writer recently witnessed the operation of a tractor known as a "10-ton artillery model" at a camp near Dover, Idaho. This big tractor is built narrower and with much greater clearance than the models previously described. It has a steel track made up of one piece links and is very long and flexible. There are six truck wheels on each side. It is driven with a 55 h. p. heavy duty motor.

This tractor would dash into the timber, climbing over stumps or crawling over low spots in the soft earth. The steel tracks would drape over a log like a rope. Then the machine would spin around a standing pine, grab a 1,500-foot log and snake it back to the road almost as quickly as we can tell the story. The ease with which this engine negotiated rough going was remarkable. It is easy to understand the respect with which Ludendorff's men regarded the tanks. For the belt tread tractor is the tank converted to uses of peace.

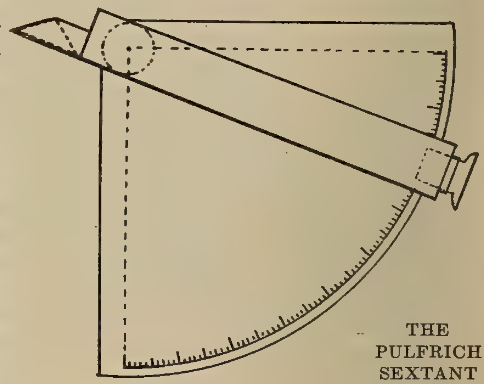
THE PULFRICH SEXTANT.

F. J. B. CORDEIRO.

HITHERTO observational navigation has been impossible at night. With the coming of darkness, the horizon vanishes and with it all possibility of taking an altitude. On land, artificial horizons consisting of surface of quicksilver, molasses, etc., are substituted, but at sea those are impossible. A horizonless sextant has long been a great desideratum and attempts have been made to obtain the necessary level surface from which to measure an altitude by attaching a spirit level to an ordinary sextant, but the success has been meagre. The reflected image of the observed object is brought into line with the bubble and the observer tries to estimate when the centre of the moving bubble coincides with the object.

Many years ago, I was shown such a "bubble" sextant by a nautical instrument maker in San Francisco. He told me that he rarely sold one and that they were of use only in certain cases where a result having a wide margin of unknown error was better than having no measurement at all.

Several years ago the first horizonless sextant which could lay any claim to accuracy, was constructed by Dr. Carl Pulfrich, head of the department of instruments of precision, (Mess-Abteilung), of the Carl Zeiss works of Jena, Germany. Dr. Pulfrich represents a type hitherto rare outside of Germany, viz., a man of high scientific attainments engaged in commercialized science. Had it not been for his patient and ingenious experimentation, it is doubtful if we should have had such an instrument for many years. When he has once decided that an idea is feasible and desirable, there are few men abler to put it into practical form, as is evidenced by the many valuable instruments he has produced.


THE PULFRICH SEXTANT

The figure represents the instrument diagrammatically. It is essentially a sector carrying an arm which supports a small telescope. In front of the objective is an isosceles reflecting prism, rigidly attached, its base being parallel to the axis of the telescope. The sector which is graduated, and the arm which moves over it, are pivoted at the center of the arc, and the whole is supported on a handle behind the sector (not shown) as in an ordinary sextant. The pivot is supplied with ball bearings and has practically no friction.

The arm with its appurtenances, clamping screw, vernier, shade glasses, etc., which are not shown, is accurately balanced about the pivot, so that the instrument, which is weighted, always hangs in precisely the same position. There is a spring (not shown), worked by the pressure of a finger, which clamps the sector so that it cannot oscillate, and at the same time removes all pressure from the ball bearings. The graduations, for equal arc, are twice as many as in the ordinary instrument, for here a quadrant is a quadrant and not an octant. The prism serves as a collimator. The rays of a star pass partly through the prism and partly through clear air, so that it is possible by adjusting the area blocked by the prism to have the direct and reflected images of equal brightness.

As the instrument pendulates, the direct image moves one way and the reflected image the other way, but twice as far. By a touch of the finger, it is easily possible to bring the pendulation to a stop momentarily, and this momentary coincidence of the two images gives us our measurement. Even with a slight movement, it is easy to judge when the excursions of the reflected image, above and below the direct image, are equal, and this gives us our point. There is no such thing as "Dip" to be corrected for, and there are conditions of the atmosphere, resulting in an abnormal refraction of the horizon line, when the readings by this instrument will be more accurate than by the ordinary sextant. The radius of the sector is about 4 inches and the instrument weighs under a pound.

I visited the Zeiss works in 1908 and again in 1911. During the latter visit, I was easily able to confirm what Dr. Pulfrich had previously told me, viz., that it was possible with this instrument to measure an altitude accurately to one minute of arc. This is all that is required for accurate navigation. The manipulation of the instrument is as easily acquired as that of an ordinary sextant.

The present interest in the instrument lies in the fact that we are now entering upon an era when trans-ocean voyages in airships will undoubtedly become matters of routine, and navigation will have to be done with Pulfrich sextants. Certain portions of the ocean are habitually covered with low-lying fogs, but the airship sails over these and for the greater part of the time, both day and night, sights will be obtainable.

The instrument will be a boon to explorers enabling them to lighten their impedimenta by dispensing with heavy flasks of mercury troughs, etc., hitherto necessary for artificial horizons.

Scale Effects in Relation to Aerodynamics*

Testing Aeroplane Parts in Wind Tunnels

By H. Levy, M.A., D.Sc., F.R.S.E.

IN all branches of engineering design the question of scale effect is one of vital consequence. With almost the sole exception of those cases where the mathematical theory of elastic structures has enabled us to design the full-sized construction from a direct calculation of the forces and stresses that will be brought to play upon it, experimental investigations on models are the only means to hand for supplying the data upon which the full-scale design is to be based. Before such an investigation can be considered admissible however, the basis of prediction from the model to the full scale must be laid secure.

In no branch of engineering is this question of more vital consequence than in the new science of aeronautics. Full-scale experimental work in this subject, invaluable as it has been, particularly during the recent war, can never in the nature of things undertake the fine and delicate tests on all the numerous details and refinements that mean so much in the design and construction of a machine in which every inch of improvement is worth fighting for.

Full-scale scientific investigations on airplanes in actual flight suffer from the two inherent disabilities which in all first-class research one seeks to eliminate—(a) the temperamental defects of the pilot and (b) inadequate knowledge and utter lack of control over the atmospheric conditions.

If it be realized that an up-current of as little as 1 per cent may involve an error in the drag measurement of the wings of as much as 15 per cent., it becomes at once evident that only by an immense series of checking and rechecking by numerous test flights could full-scale research under actual flying conditions serve alone as a basis for design. Experimental means, moreover, for direct measurement of the forces brought into play during flight are not likely for some considerable time to be so far developed as to allow of a determination of the isolated effects of the small variations in design which together in the end sum up to considerable importance. The advantage that experiments on models in the wind tunnels possess over those on the full scale and in the open becomes at once apparent. Complete control can be exercised over the experimental conditions both as regards wind speed and the isolation of the effects on resistance and consequently on performance due to slight modifications in design. But these advantages are only to be had at—in many cases—the expense of facing an extremely serious difficulty—viz., the problem of scale, and it is with this aspect of the question that the present article is primarily concerned.

The construction by means of which the forces on the models are measured is shown in Fig. 1. It consists essentially of two rectangular horizontal wooden tunnels connected by a slightly tapered portion containing the propellor. When the latter is in operation the air is sucked in through the inlet and along the front or working portion of the channel. At the inlet mouth is situated a honeycomb to steady the flow and distribute the air uniformly along the channel.

Almost midway along the working portion, where the distribution in velocity across the section is most uniform, is placed the model fixed to a vertical support through the floor of the channel, forming a portion of the balance by means of which the forces and moments exerted on the model are measured. The air then passes through a second honeycomb, through the propellor and is discharged into the outflow distributor. The walls of the latter are composed of vertical laths spaced progressively to allow as far as possible of the passage of the slip stream air back into the room without the production of excessive turbulence by splashing against the wall.

Looked at in plan, the flow of the air in the room is as indicated in Fig. 2, and by such a symmetrical system the streaming in the tunnel proper can be maintained at a high degree of steadiness and uniformity. It is not until a distance of 1 in. from the wall is reached that any appreciable drop in the velocity is found. The wind speed in the channel is regulated by adjusting the revolutionary speed of the propeller in the usual fashion. In utilizing the wind tunnel for aerodynamic research two different classes of measurement are essential: First, the accurate measurement of wind speed, and, secondly, the measurement of the forces brought into play. The instrument upon which the measurement of wind speed depends is known as the Pitot tube. The general outline is shown in Fig. 3. It is composed of two hollow tubes fitting one inside the other and closed along the circular edge *AB*. The outer tube is perforated at the points *CDE* —and open again to the outside at *F*. The inner tube is open both at the front *AB* and at the end *G*. The fore part *LM* is placed parallel to the wind *V* whose speed it is required to measure. A tube of this nature moved on the end of a whirling arm is found by experiment to acquire in the inner tube,

*From *Automotive Industries*.

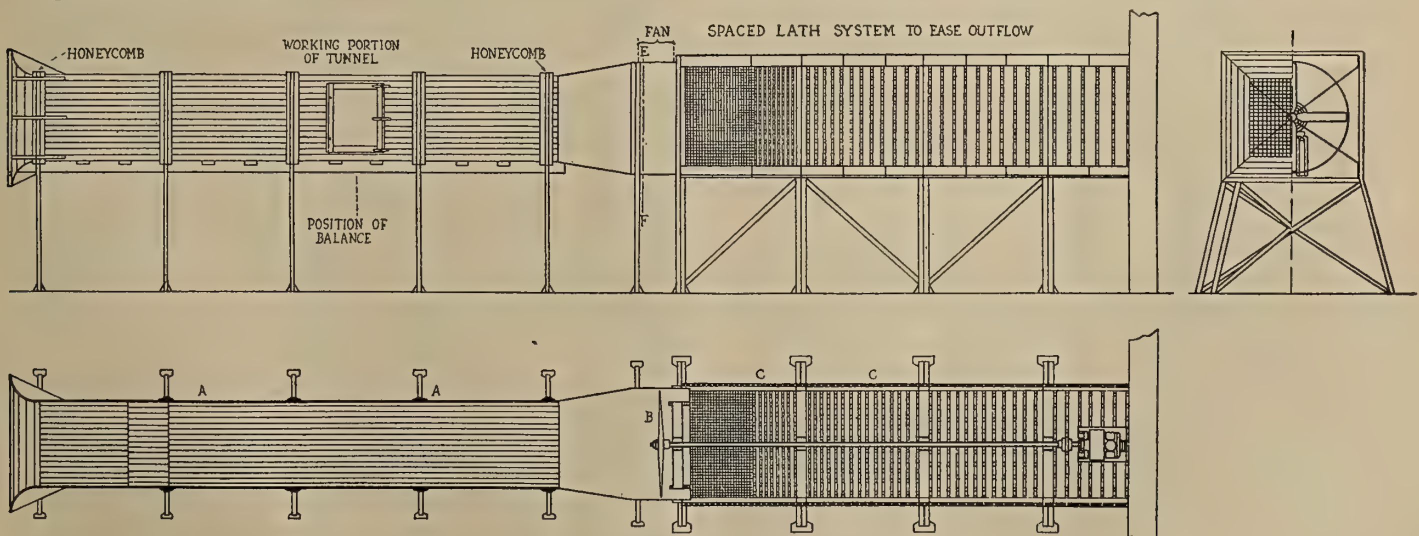


FIG. 1—THE NO. 1 4-FOOT CHANNEL

in addition to the ordinary static pressure p_o, an additional dynamic head given by $(\frac{1}{2})\ \rho v^2$, where ρ is the density of the air in gravity units and v is the speed. This total pressure $p_o + (\frac{1}{2})\ \rho v^2$ is usually transmitted to one end of a pressure gage. At the perforations *CDE*, etc., where the stream is parallel to the surface, there is no additional dynamic head, and the pressure at the outlet *F* is therefore p_o, the general atmospheric pressure. This is transmitted to the other arm of the pressure gage and balanced against the pressure $p_o +$

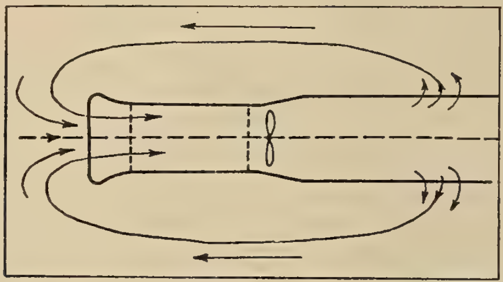


FIG. 2—DIAGRAM SHOWING FLOW OF AIR IN ROOM

$(\frac{1}{2})\ \rho v^2$. The weight of the column of liquid between the two levels in the gage is consequently $(p_o + [\frac{1}{2}]\ \rho v^2) - p_o = (\frac{1}{2})\ \rho v^2$, and from a measurement of this difference in level the velocity can easily be calculated.

A diagram showing the form of the pressure gage is given in Fig. 4. This difference of pressure between the two cups *A* and *B* shows itself by a rising or falling of the meniscus *M*. This may be compensated for by a measured number of turns of the screw wheel *W* which alters the relative level of the cups. The alteration of level read off from the scale *S* is thus a measure of the difference in pressure between the two cups.

A detailed description of the balance in use in most aerodynamical laboratories for the measurement of wind forces on models will not be entered into here, but for the present it is sufficient to state that the principle on which it is based is to balance the moments due to the component wind forces—drag along the direction of the wind, cross-wind force perpendicular to that direction in the horizontal plane, and lift in the vertical plane—by applied external moments. With a model whose weight does not exceed 3 lb. the balance is sensitive to 0.0001 lb. and to much less for very light models.

It is clear that by means of these highly delicate appliances

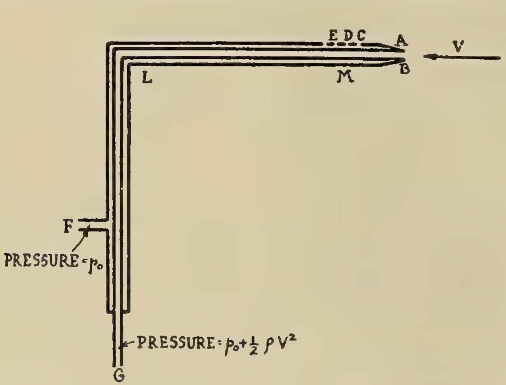


FIG. 3—DIAGRAM OF PITOT TUBE IN AIR SPEED METER

the aerodynamic properties of bodies of all possible shapes, and the modifications due to slight changes, may be investigated to a great degree of precision, but it is also clear that unless the laws of prediction of the forces operating on full-sized machines or parts, at the high speeds of flight occurring in practice, from those measured on models at wind tunnel speeds, are equally precise much of this work would be futile. Even were the laws of transition not known, however, there is still the possibility of deriving useful information by mere comparative methods.

AS TO CHANGES

For example, if it be found that a particular modification—it may be a change in wing section, a change in cross-section of strut, etc.—involves an improvement in the design of the model indicating itself in a more efficient performance, there is a presumption that the same modification will involve an increased efficiency on the complete full-scale machine. How to estimate this increased efficiency in magnitude in the latter case from that measured on the model is, however, a question of much more vital consequence, for upon it will depend ultimately our power of designing aircraft for specific functions and placing reliance on the results. It will be seen that an answer to this can be provided—complete for all practical purposes—by nothing more than an application of the classical dynamical laws of Newton.

In order to clear the ground, certain experimental facts bearing on the question may be briefly recalled. If two bodies of identical shape but one twice the other in size be tested for air resistance in a wind tunnel, it is found that the resistances are equal if the larger model is tested at half the wind speed of the other. Generally, in fact, if the shape of a body be given by a drawing and the length of one part be represented by l which determines the size of the body, then if v be the

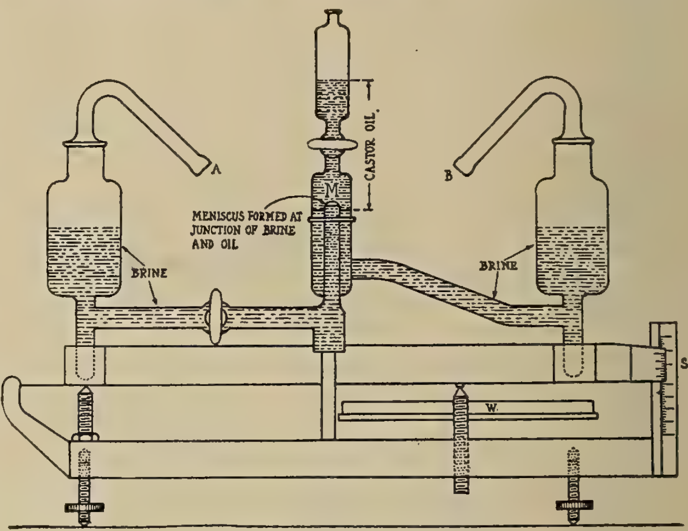


FIG. 4—AIR PRESSURE GAGE

wind speed, so long as $v \times l$ is maintained constant, the resistance remains constant.

This suggests immediately that in air the wind forces exerted on a body are purely a function of the product $v \times l$. We may arrive at this result, however, from very general considerations without reference to experiment. The forces operating on a body can only depend on the size l of the body, its shape, the density ρ and viscosity ν of the air, and its wind speed v. In effect this implies that the expression for the resistance must contain these quantities and these quantities only. We have at the same time the general principle in dynamics that the dimensions of such an expression must be those of a force since it is equated to a force. How then are the quantities l, ρ, ν and v to be grouped together to give an expression having the dimensions of a force? As a mathematical problem this is quite simple and indicates that the resistance R must be represented in the form

$$R = \rho v^2 l^2 f \frac{vl}{\nu}$$

It is particularly to be noted that the exact form of the function $f(vl/\nu)$ is so far indeterminate and will depend purely on the shape of the body under consideration. Two bodies of the same shape but of different sizes moving at different speeds will have the same *form* of expression for f, but vl/ν will have distinct values for each case. As long as the two bodies are moving in air, ρ the density and ν the viscosity will remain

fixed, and it follows at once from this formula that if $v \times l$ is maintained constant the resistance will be the same in both cases in accordance with the experimental fact already referred to. The accuracy of this formula has been subjected to many searching tests, not (be it noted) to check whether the dynamical laws upon which it is based are valid, but to determine whether or not it is justifiable to assume that in all cases the forces depend only on the quantities stated.

WORKING OUT FORMULA

The formula suggests that for all such aerodynamical investigations the most suitable manner of presentation is to plot the resistance coefficient $R/\rho v^2 l^2$ against vl/ν. The curve thus obtained should represent the form of the function f, and all points derived from experiments on bodies of the same shape should, irrespective of the size of the latter, fall on this curve.

The equation

$$\text{resistance coefficient} = R/\rho v^2 l^2 = f(vl/\nu)$$

states that as long as the experiments to be compared are conducted in air, and this is evidently satisfied by comparative aerodynamical tests in the wind tunnel, the force coefficient will depend only on the value of vl at which the experiment is conducted. It follows at once therefore that if experiment enables us to cover a wide enough range of this product the determination of the forces on the full scale could be derived by drawing up an experimental chart showing the variation in force coefficient with vl and selecting the ordinate at the appropriate full-scale value of this quantity.

Fig. 5 gives such a chart for the best strut so far obtained. In this case the resistance coefficient is represented as the resistance coefficient per foot run of the strut, the standard dimension l used in the foregoing discussion, selected in this case to represent the shorter diameter of the cross-section. If in an actual strut $l = 6$ in. $= \frac{1}{2}$ ft. and $v = 120$ ft.-sec.

$$vl = 60.\ \text{ft.}^2\ \text{sec. units}$$

and the curve indicates that the resistance coefficient for this value of $v = 0.04$.

A point of extremely general significance is illustrated by Fig. 5. The resistance coefficient, of very large magnitude for low values of vl, falls rapidly, and for large values of vl ultimately approaches a constant value, but when the resistance coefficient is constant the resisting force is proportional to the square of the velocity, and this therefore is the law for a strut moving with comparatively high speed. But this result is not peculiar to a strut; for practically all bodies of aerodynamic shape it is found that if the resistance be measured up to high enough valves of $v \times l$ this force tends ultimately to become proportional to the square of the velocity, and this is probably the case for bodies of the magnitude of those occurring in a full-sized airplane flying at its normal speed. It follows at once that if the wind tunnel tests can be continued up to such a value of $v \times l$ as render the resistance coefficient sensibly constant, the constant of proportionality is at once determined and the magnitude of the forces on the full scale can immediately be estimated.

Unfortunately, however, for the complete success of this method, the disparity between the values of $v \times l$ for the model and for the full scale is extremely great and it is frequently necessary to extrapolate over an extremely large range of $v \times l$. The relative extent of this extrapolation becomes clear from a simple calculation. If the chord of an airplane wing is 6 ft. and its wind velocity 100 ft.-sec. the corresponding value of $v \times l$ is 600 ft.^{2}sec. units, while for a model test on a wing the chord is rarely greater than 6 in. at a wind speed of 60 ft.-sec., giving a value for $v \times l$ of 30. An extrapolation of, from 30 to 600, appears an extremely large range with a probably high degree of inaccuracy, but in practice the error thus occasioned is more apparent than real. In most cases that arise either the curve for the resistance coefficient has become sensibly constant before the limit of the experimental range is reached, or it is rapidly becoming so.

It is at this stage that full-scale experimental investigations on machines under flying conditions play an important part in acting as a check and supply correction or confirmation to the model results. Systematic and continuous comparison has now been carried through for several years and the conclusions have been arrived at, that no very serious errors creep in as a result of these extrapolations, provided certain factors are used with discretion.

A WARNING

One evident source of trouble is possible, however, and must be guarded against. It has been shown that the resistance coefficient depends entirely on the value of $v \times l$ at which the experiment is conducted; but a wider point of view than this can legitimately be adopted. All the phenomena of the motion, the nature of the flow and stream lines, the occurrence and period of the eddies will all likewise depend

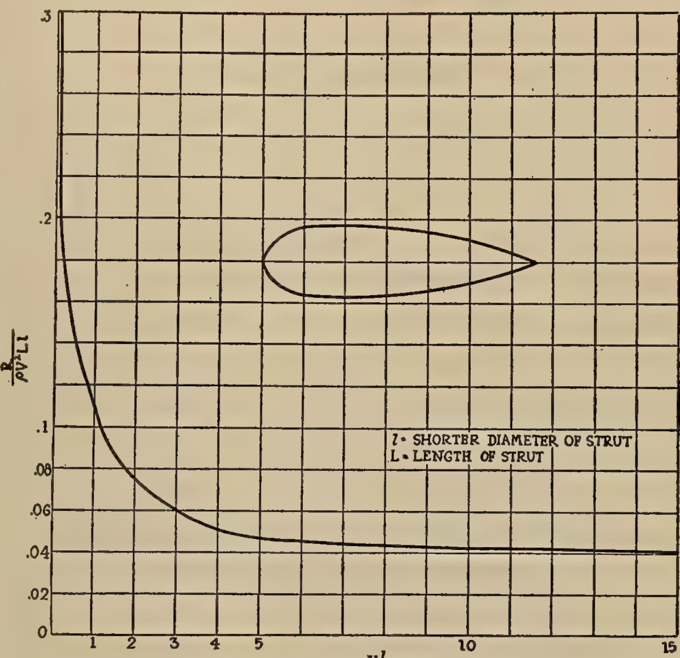


FIG. 5—RESISTANCE COEFFICIENT CHART FOR AIRPLANE STRUT

on this value. Now it is found experimentally that certain critical values of $v \times l$ exist for any given body, in the region of which the nature of the flow undergoes rapid change, accompanied by a simultaneous rapid alteration in the value of the forces originated. It has, for example, been found that certain struts at a given wind speed may indicate as many as three different values for the head resistance according, apparently, to the nature of the flow of air in its neighborhood. The value of $v \times l$ at which this occurs is clearly extremely critical. The three separate resistance curves thus indicated would not be equally stable, and at much higher values of $v \times l$ two of them would disappear. If a false extrapolated value is not to be obtained, it is evident that the experimental range of $v \times l$ in any given case must extend well beyond any region in which such critical values may arise.

There is one branch of aeronautical engineering in which the difficulty as regards scale effect does not arise to any measurable extent; that of propeller design. In this case there is an extra complication in the question which did not enter in that of the steady motion of a body—viz., the fact that the propeller is rotating at a definie angular velocity, say n rev. per sec. in addition to its forward motion. If D is the diameter of the propeller, then, following the lines indicated earlier in the article as regards the form which the forces must take, in this case the thrust and torque, it can be readily shown that these quantities must depend on the quantity V/Dn in addition to VD/ν as before. Ample evidence, however, exists to indicate

that in general the effect of the viscosity term is negligible. This would be so if on plotting the thrust coefficient on a base V/Dn the points corresponding to different values of VD/ν all fell on one single curve instead of a series of such curves. That some form of scale effect might arise is evident on general considerations from the fact that each elemental section of a propeller blade may be considered as of the nature of an aerofoil each portion of which as already seen would produce its own scale effect. Whether these sum up to any appreciable magnitude is quite another matter. Taking a propeller of 6-ft. radius with a mean chord for the aerofoil section 3 ft. from the boss as 5 in., rotating at a speed of 1200 r.p.m., for a static propeller of this nature the value of $v \times l$ would be approximately 160, which is normally well beyond the range at which any scale effect shows itself appreciably. On general grounds, therefore, it is not to be anticipated that the term VD/ν will enter into the equation at all, and this conclusion has been borne out in so many actual cases that have been tested that it may be considered of general application.

SCALE CORRECTIONS

It may therefore be accepted that in order to investigate the properties of propellers, results obtained on models need not be corrected for scale effect, so that the force coefficients, efficiency and other general properties of the propeller will depend merely on the value of V/Dn at which the test is made and experimental means for a model can always be devised to cover the complete range of this quantity required in practice.

NON-DIMENSIONAL COEFFICIENTS

In the foregoing discussion reference has been made in each of the classes of problem dealt with to certain groups of terms by studying the variation of which all the properties concerned may be treated. Such a quantity in the case of problems of the motion of viscous fluids, of the forces on struts, wires and airplane wings is Vl/ν, and in the case of a propeller V/Dn. For every physical problem, whether concerned with aeronautics or not, some such groups of symbols exists with the variation of which, as it were, all the properties may be considered. Now, if we consider the dimensions of these groups of symbols, what do we find?

Quantity	Symbol	Dimension
Speed	V	L/T
Length	l or D	L
Viscosity	ν	L^2/T
Angular speed	n	$1/T$

The dimensions of Vl/ν and of V/Dn are evidently from this table zero, and it follows at once that the value of both these quantities will be absolutely independent of the system of units in which it is expressed, provided all the quantities concerned are expressed in a consistent set of units. An illustration of the same idea from another branch of engineering will be familiar to the reader. The buckling of a homogeneous untapered strut or column, by end thrust takes place when the latter reaches the value

$$F = \pi^2 EI/l^2$$

where E is the elastic constant for the material, l the length of the strut and I the moment of inertia; but this may be written

$$\frac{Fl^2}{EI} = \pi^2$$

and a consideration of the dimensions of the expression on the left-hand side shows that it is non-dimensional. No matter in terms of what units the various quantities are measured, provided they are self-consistent, buckling will always take place when this quantity becomes equal to π^2.

In the same way, if a series of struts, tapered or otherwise, all geometrically identical as regards outline but of different sizes, be tested for buckling as a class, they will all fail when Fl^2/EI reaches some definite fixed value, where EI is the flexural rigidity at some standard section along the length, say the mid-section.

The initial step, therefore, in analyzing any physical or engineering problem by experimental means is to determine the group or groups of non-dimensional terms by whose variation the properties may be studied. Any function of these non-dimensional quantities will itself be non-dimensional, of course, and consequently we have such expressions as

$$R/\rho v^2l^2 = f(vl/\nu) = \text{non-dimensional quantity} = k, \text{ say.}$$

$$T/\rho n^2D^4 = F(V/Dn) = \text{non-dimensional quantity} = T_c, \text{ say.}$$

The quantities T_c and k, etc., are non-dimensional coefficients from the value of which at any speed, translational or rotational, and for any size the various force components may be calculated.

The analysis of all these problems centers round a consideration of the value adopted by these coefficients as vl/ν and V/Dn changes. Containing thus the essence of the problem from the theoretical aspect, they embody at the same time the simplest method of representation. The magnitude they adopt for any value of vl/ν or V/Dn is independent of the system of units used, whether in ft.-lb.-sec. or c.gs. units, while the forces required can be obtained directly my multiplying by ρv^2l^2 or ρn^2D^4 in the appropriate units.

A NEW THEORY OF REINFORCED CONCRETE.

IN the Comptes Rendus de l'Académie des Sciences for July 7th, 1919, Mr. Vasilesco Karpen advances a theory to explain the adhesion of concrete to iron in reinforced concrete structures.

This adhesion, he says, is an essential factor in the resistance of reinforced concrete, but its cause and results seem to be unknown. It is usually considered as due to a glue-like action, analagous to the adherence of mortar to brick. Experience, however, does not confirm this view, for if cement is poured on an iron plate the adhesion is far from having the value that it has in reinforced concrete, and if the surface of the iron is smooth or oily, there is no adhesion. On the other hand, tests made with bars embedded in concrete show that adhesion occurs, even when the bars are painted or oiled; evidently there is no action similar to glue in these cases.

The author believes that the unified action of iron and concrete in reinforced concrete structures is due to the friction of the iron against the concrete. It is known that concrete contracts in setting; in so doing it grips the iron which it surrounds and resists attempts to separate the two.

Figures are given showing the results to be expected if this theory is correct, which agree closely with those obtained in practice. It has also been shown by practice that the adhesion of concrete, and its contraction, increase with time. The friction due to the contraction of the concrete around the iron is sufficient to explain the unity of the iron-concrete combination.

When reinforced concrete structures are demolished, the concrete ceases to cling to the iron as soon as it ceases to surround the iron entirely.

In calculating reinforced concrete, it is the general custom not to count upon any resistance of the concrete to tension. The present theory, on the contrary, shows that it is precisely because of the resistance of concrete to tension that it presses against the iron and produces the necessary solidity of the united materials.

By this theory the thickness of concrete required about the iron may be determined from a consideration of the tension, which must not exceed the admissible maximum.

Mr. Karpen's theory also calls attention to the great importance of a knowledge of the coefficient of contraction of cement.

Aerial Passenger Travel at High Altitudes

Aerial "Diving Suits" and "Submarines"

At a meeting of the "Scientific Commission" of the Aero Club of France, held April 30, 1919, an address was made by Dr. Guglielmimetti with respect to the physiological probems involved in air travel at high altitudes. Dr. Guglielmimetti is a celebrated physiologist and for many years has devoted himself especially to the study of the effects of altitude upon the organs of the human body. He is of opinion that the most feasible method of carrying passengers through the air is at high altitudes in cabins wherein a normal atmospheric pressure is maintained. Such a cabin obviously bears an analogy to a submarine. We quote below a portion of his address from a report in a recent number of *L'Aérophile* (Paris).

Rapidity of movement is one of the factors concerned in the safety of an airplane since it is by this that the latter is sustained in the air. . . . It is at very high altitudes apparently that the amosphere is most propitious to high rates of speed: since the air is lighter it offers less resistance—an avion which travels 150 km. per hour at a height of 5,000 m. is capable of travelling 300 km. per hour at 1,600 m. Moreover the air currents, provided they are favorable, are far more rapid at such altitudes and are regulated by laws which are better known or which are at any rate more general in application than those which regulate the wind at lower altitudes. . . . It lies with the meteorologists to decide at what height new international, transcontinental and transoceanic routes should be laid out.

But can the present day motors carry us at these high altitudes? This is a matter which must be referred to engineers and builders. In rarefied air the motor has need, like the man, of a supplementary supply of air. M. Rateau, a member of the Academy of Sciences, has had the ingenious idea of attaching to the escapement valve a turbine driven by the exhaust gases at a rate of 30,000 revolutions per minute. This motor drives a small centrifugal ventilator designed to compress to the normal pressure the air required by the motor.

At the Aerotechnical Institute of St. Cyr, the Technical Section of Aeronautics has installed an enormous exhaust caisson in which Dr. Garsaux has made obsevations upon the effect of different altitudes upon aviators. Captain Toussaint, the well-known authority upon aero-dynamics, intends to make use of this same caisson in experiments upon motors with respect to the work done at various altitudes.

We now come to the question which interests us specially: is it possible to transport persons in good health to high altitudes in the space of a few minutes without disturbing their health, and if so to what altitude? Is the organism capable of supporting these great variations of pressure and will the diminution in the tension of oxygen permit the organism to survive, with a supply of oxygen?

The researches of Paul Bert have taught us that the troubles comprised under the name of "altitude sickness" proceed from two causes: The sudden variation of the pressure and the influence upon the organism of the rarefied air. Let us explain by examples.

A. If we place two sparrows under a bell jar in which the air has been rarefied, when the barometric pressure within the bell jar has descended to 300 m/m—which corresponds to an altitude of about 7,000 m.—the birds exhibit signs of illness, at 200 m/m (an altitude of 12,000 m.) they stumble and stagger and then fall over and it makes little difference whether this depression has been attained slowly, i. e. in the course of a quarter of an hour, or in only four or five minutes.

If we continue to exhaust the air until the pressure falls to 180 m/m (an altitude of 15,000 m.) the birds become violently agitated and die in a few seconds. If oxygen be now passed into the bell jar the birds immediately recover. It has been proved that the illness thus produced in the birds is due entirely to the lower tension of the oxygen in the blood, for if hydrogen be allowed to enter the bell jar instead of oxygen, the barometer at once ascends and the pressure becomes normal, but the birds fail to recover.

B. When two guinea pigs are enclosed in the same bell jar containing rarefied air, but one of them is allowed to remain at rest, while the other is forced to experience great fatigue (by means of a tread mill, for example) the latter animal will fall ill at a rarefaction corresponding to about 4,600 m., while the former will not exhibit indubitable altitude sickness until a rarefaction corresponding to about 8,000 m. is attained: If the air under the bell jar has been previously saturated with oxygen however, the rarefaction can be carried much further without the slightest symptom of sickness being exhibited. It is evident that the animal at rest represents an aeronaut while the animal forced to exert itself actively represents a mountain climber.

This question of the influence of rarefied air upon the human organism is one with which I have long been intensely preoccupied. Having been born in the neighborhood of the Simplon, which poor Chavez was the first to fly over, giving his life to the cause of the progress of aviation, I climbed in my youth most of the lofty peaks of this mountainous region. I was very often sick but like nearly all Alpinists I attributed this to fatigue, to the lack of sleep in the not very comfortable cabins, or to stomach disturbances. After climbing hour upon hour one is exhausted when one arrives at the top of the mountain, so that one takes but little account of the effect of the rarefaction of the air, and then when one descends he feels better just as he gets over being seasick when the boat stops.

I had a very lively desire to make a prolonged sojourn upon the top of a lofty mountain, in the first case so as to eliminate fatigue from my observations and secondly to see whether it is possible for the human organism to acclimate itself readily to higher altitudes. About this time it was planned to construct a railroad to the top of the Jungfrau (4,000 m.) which gave special interest to the question. The Federal Swiss Council withheld its consent to this project until it could be determined what risks would be run not only by the train crews and the workmen employed in construction, but by the passengers. In 1891, a unique opportunity presented itself—the Jansen Expedition for the building of an observatory at the summit of Mont Blanc at a height of 4,807 m.

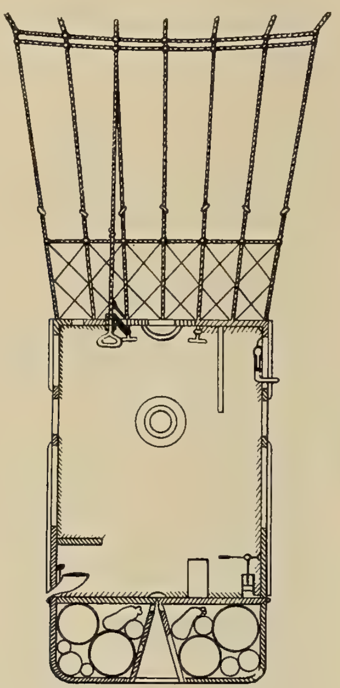
This expedition was to stay for several weeks in the Vallot cabin at a height of 4,600 m. One of my confreres and myself offered to give our services to the members of the expedition—some thirty guides and porters of Chamounix—and to make certain observations upon ourselves.

We all suffered more or less from mountain sickness. This malady is characterized by profound and accelerated respiration (which had but little efficacy), by an increase in the heart beat up to 120 beats per minute, by headache, by nausea, and by general exhaustion. The slightest effort induced a feeling of suffocation and an acceleration of the pulse up to 160 beats per minute. The laborers were employed in digging a tunnel through the summit of the mountain in order to find a rock suitable for the base of an iron observatory, which our colleague M. Eifel purposed to build. Upon observing these men I found that though they were accustomed to the mountain air they were not able to give more than a dozen strokes of the pick or to lift more than ten shovelfuls of snow before finding it impossible to continue and having to be relieved in order to get their breath. Along

about the fourth or fifth day, however, we had all become acclimated except for two porters, who were ordered to descend to the Grand Mulet for fear of serious accident. Dr. Jacottet of Neuchatel, who had requested to take my place for a few days, died in the Vallot cabin the third day after his arrival, from mountain sickness.

But these results obtained in mountain climbing must be compared with observations made in balloon ascents; the latter differ by being more rapid both in the ascent and in the descent and by imposing no especial fatigue upon the organism. It was with the purpose of making such observations that I organized the first series of physiological balloon ascents by means of which it was proved that from 5,000 m. the intimate combustions, the respiratory exchanges in the tissues are augmented to a degree which it was not possible to foresee.

Usually no noteworthy disturbances are experienced in a balloon up to 5,000 m., but from this point onward nearly all balloonists suffer and are unable to resist the effects of the rarefaction of the air except by continuous inhalations of oxygen. In 1912, Lieut. Bienaimé with two passengers reached the altitude of 10,107 m. (the French record); he began inhalations of oxygen at 4,000 m. taking 3 liters per

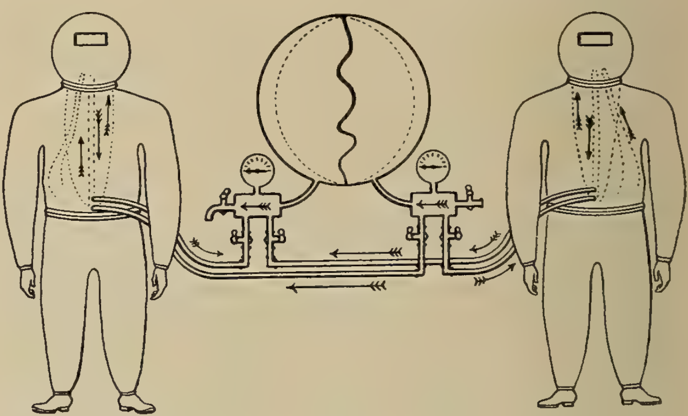


CLOSED CAR FOR HIGH ALTITUDE BALLOONING.

minute and keeping on his mask continuously. He made the ascent without feeling the slightest illness, but one of his passengers who took off his mask every two minutes in order to throw out ballast became unconscious at 8,000 m.; however, he was soon restored by a greater absorption of oxygen.

The world record of altitude belongs to Drs. Berson and Suhring, who ascended to a height of 10,800 m. in 1911. They acknowledged frankly having felt as if they were actually paralyzed, incapable of deciding to make the slightest movement and in spite of their inhalations of oxygen it required all their energy to keep from giving way to an almost invincible sleepiness. As soon as they stopped inhaling oxygen for a few minutes, they suffered increased heart palpitations and began to stagger. An English scientist, Glaisher, with a companion named Coxwell, ascended to a height of 8,860 m. He suffered greatly from balloon sickness and complained especially of the great difficulty of using his arms which felt as if paralyzed. He had not inhaled oxygen and he fainted in the car at about 7,000 m. in height. Another English aviator, Lang, ascended to an estimated height of 9,500 m. with a passenger; the latter fainted at 7,500 m. because the tube leading oxygen into his inhaler was broken.

It is interesting to compare two ascensions made twenty years apart to show the progress made with respect to respiratory apparatus. The first was that of the Zénith which rose to 8,600 m. piloted by Tissandier, accompanied by Croce-Spinelli and Sivel, and the second was the ascent made by Colonel Bolsan and Godard in 1900 to 8,553 m. Paul Bert himself made the prelimintry arrangements in the first case. Together with his pupils, Croce-Spinelli and Sivel, he entered one of the pneumatic bell jars at the Sorbonne and observed that the beneficent action of oxygen enabled them to avoid injury by the rarefaction of the air. Full of confidence in his theory the two younger savants started gaily for their trip on board the Zénith. They carried oxygen with them but it was enclosed in small bags such as are used in cases of illness. Two hours later when the balloon reached earth again the two young men were dead. Tissandier alone survived and he, too, had fainted. . . . According to the log kept by the pilot all three had inhaled oxygen but not until they reached a height of 6,500 m. This was rather late to begin and furthermore, little oxygen was consumed since the bags were found almost full. Crocé and Sivel went to sleep at about 7,100 m. and probably passed away in slumber. . . . When one is attacked by altitude sickness he experiences a considerable prostration and a mental depression which makes him absolutely indifferent to all danger; the will is paralyzed as in seasickness. One has but a single desire—to



DIVING UNITS FOR FLIGHTS AT HIGH ALTITUDES.

be left utterly alone and allowed to go to sleep, even on a bed of snow at a temperature of 20° C. below zero. One feels neither cold nor danger, but to go to sleep in this manner means to wake in another world. Good mountain guides know this and prevent climbers from going to sleep. Undoubtedly Crocé and Sivel became stupefied and lacked both the will power and the strength to catch hold of the oxygen pipe which hung above them and which would have saved their lives.

Compare with this case the ascent made by Balsan and Godard to about the same altitude. Colonel Balsan has told me that he found it beginning to be difficult to work at a height of 6,000 m. though he had commenced to inhale oxygen at 4,000 m. He suffered greatly and found it impossible to carry the oxygen tube to his mouth, his hand remaining motionless at a distance of 10 cm. and his will failing to exert itself. Godard hastily passed the tube to him and in two minutes he was better. When Godard was sick he experienced the same impossibility of action. . . . Dr. Schroetter of Vienna made a sphygmographic tracing at 7,500 m. which was absolutely normal, thanks to the oxygen inhalation which enabled him to perform at this altitude delicate and difficult mental and physical operations.

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There is little to be said with regard to the symptoms of compression experienced during descent. M. Mallet has told me that he suffered more in the descent from a height of 7,000 m. than in the ascent, and Lieut Bienaimé complained

of experiencing troubles of circulation the day after making his record ascent. . . . But aside from the rarefaction of the air sudden variations of pressure are to be feared . . . finally, the question arises whether ordinary passengers will be able to navigate in the upper reaches of the air. The answer must be—No. All these aeronauts are either young sportsmen or picked men who have been subjected to a severe training which passengers could hardly be expected to undergo. Then, too, there might be found among the latter those suffering from unsuspected troubles of the heart and blood vessels which might cause great variations of pressure to be fatal to them. . . . Further more, for some unknown reason many persons cannot even bear the comparatively low altitude of 2,000 m. In my medical work at Zermatt (1,800 m.) I have seen travellers arrive from Paris and London who felt perfectly well until they had mounted the stairway of the hotel, when they suddenly experienced disturbing and even alarming symptoms; these generally abated after a night's rest but it was sometimes necessary to send such persons into the valley to avoid serious accidents.

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Let us now consider suitable remedies for altitude sickness.

Improved and automatic respiratory apparatus may suffice for aviators whether sportsmen or military men, but if passengers are to be transported it is hardly feasible to think of providing them with similar masks, not only because these would considerably interfere with the pleasure of the voyage, but because they do not offer a sufficient guarantee against illness. . . .

By means of diving bells, diving suits, and submarines, man is enabled to live in a *milieu* which provides no element to satisfy his lungs. Why could not similar apparatus be devised for use in the upper regions of the air? The accompanying diagrams show devices proposed to meet this end. The first is a closed cabin in which both passengers and pilots are surrounded by a normal atmospheric pressure which can easily be maintained by means of a pump. The weight of such a cabin holding twelve persons need not be more than two or three hundred kilograms, if composed of duralumin. The technical problems involved appear to be theoretically simpler than those which have been solved in the case of diving suits and submarines; even at the highest altitudes the difference of pressure between the inside and the outside air would not exceed more than about half an atmosphere, while the walls of a submarine are required to support a difference of three or four atmospheres. Even supposing that an accidental crack appeared in the walls of the cabin so that the latter was unable to maintain the constant pressure, it would always be easy to descend to a lower altitude. . . . As a matter of fact such a cabin is now being studied by several builders and by the Technical Section of Aeronautics.

I may terminate these remarks by mentioning a project for a closed car and an aerial diving suit presented before the French Society of Aerial Navigation as long ago as 1871. . . . This car, proposed by Louis Tridon, was composed of solid and flexible portions. The solid portion was composed of a floor and roof of basket work. The roof served as a maneuvring car. At a high altitude the aeronaut was supposed to descend through a manhole into the lower car in which were placed compressed oxygen and cloths soaked in lime water to absorb the carbon dioxide of the breath.

In 1900, M. Andrieux presented to the same Society the model of an aerial diving suit, consisting of air tight canvas. A special system of tubes fed by a reservoir of compressed oxygen served to maintain around the aeronaut a sufficient pressure to cause the air to circulate in such quantities as to ensure comfortable respiration.

Since these different questions concerning the navigation of the air at high altitudes are intimately connected, and interest physicians and meterologists as well as builders, I have requested the Scientific Commission of the Aero Club kindly to invite various specialists to be present at our meetings in order to obtain an exchange of views upon this subject . . . which I hope may lead to discussion which will be of advantage to the progress of aeronautic science.

The Instinct of Orientation in Ants

The Operation of the Homing Instinct

By Dr. Rudolf Brun, Assistant in the Nerve Polyclinic of the University of Zurich

ANTS are peculiarly adapted to the study of distance orientation for two reasons: First because of their settled and social manner of life which forces them constantly to return to a definite starting point, *i. e.*, the nest, after all their expeditions, and secondly because, unlike bees, they lack wings, and it is thus easier to follow their movements during the course of experiments.

The correct understanding of such a complicated biological process as is presented by the distance orientation of ants naturally requires an exact knowledge of the anatomy and physiology of the organs of sense therein concerned as well as of the association apparatus in the brain connected with these organs. Hence I will begin my remarks by recalling the essential features of these.

The senses concerned in the orientation processes of ants are those of smell, of touch, of sight, and of kinesthetic registration. With respect to the last mentioned our information must be exclusively gained by experimental physiological analysis. With respect to the functions of the other senses the mere anatomical structure of the organs concerned furnishes us with at least partial data.

The sense of smell is by far the most important possessed by ants from the biological point of view. It is of essential importance for what I have called extero-ceptive orientation in space, because its peripheral end apparatus is localized superficially upon the symmetrical and extremely mobile jointed antennae. The sense of smell in ants belongs, therefore, like the human eye, to the *relational* senses, *i. e.* it is primarily a contact-odor sense which does not perceive the odorous objects, which are perceived at the same time by emanations from various objects as does the human nose in a diffused mixture, but, on the contrary, in a quite definite arrangement in space, corresponding to the forms possessed by the tactile hairs of the feelers. It is upon this consideration that Forel[1] has based his brilliant *contact-odor theory*, or, theory of the topo-chemical tactile sense according to which ants become aware of sharply defined "odor forms" by means of their feelers. They are able to distinguish, for example, between round and square odors, hard and soft odors, elliptical and spherical odors, and they store up in their memories associated topo-chemical engram-complexes corresponding to these odor forms in the same arrangement with respect to time and space in which they were originally perceived. Forel expressly emphasizes the fact, however, that ants can naturally make use of these topo-chemical associations only to a very

*Translated for the SCIENTIFIC AMERICAN MONTHLY from the *Biologische Centralblatt* (Leipzig).

[1]Forel Experiences et remarques critiques sur les sensations des insects.—Rivista di Sc. Biol. II and III, Como 1900-1901.—Die Psych. Faehigkeiten der Ameisen, 2. Aufl., Reinhardt, Munich 1902.—Sinnesleden der Insekten, ebend. 1910.

limited extent corresponding to the absolute smallness of their brains. . . . In comparison with the contact-odor sense the capacity for distance smelling is obviously only slightly developed in ants it is easy to convince ourselves by a simple experiment that ants are incapable of scenting for a distance of more than a few centimeters even highly fragrant substances which are particularly appetizing to them.

The sense of sight exhibits in ants as in most insects a series of peculiariies which indicate beforehand that they probably function in the matter of distance orientation in a manner different from that of the eyes of vertebrates. According to the Mueller-Exner theory of "mosaic vision" the facetted eyes of insects produce a single upright mosaic image (apposition image), whose distinctness depends primarily upon the number of the facets and secondarily upon the length and narrowness of the separate ommatidia, as the single facets of such compound eyes are termed. The eyes of the best seeing ants, those of the workers, possess a comparatively small number of facets[2] and comparatively short ommatidia. Their distance point, which usually depends upon the curvature of the lens of the cornea, is reduced in most varieties to a few millimeters or at most centimeters from the eye. The immovability of facetted eyes also has the consequence that the attention of the resting insect can only be attracted by moving objects. For this reason the eyes of ants appear to be usually suited only for the perception of large moving objects in their immediate neighborhood (Forel). On this account is was formerly generally believed that the sense of sight must play only a very subordinate rôle in distance orientation among these insects. We owe the correction of this error mainly to the work done by Santschi.[3] . . .

The question as to whether ants are able to "hear" appears to be still undecided in spite of much research. The peculiar so-called "chordo-tonal" organs extended inside the tibia have been repeatedly referred to as organs of hearing; in case, however, these are really capable of receiving true sound waves, they are probably confined to the perception of those very delicate chirping sounds or "stridulations" (in the immediate vicinity) which many ants produce by the rubbing together of certain parts of their armor of chitin. As regards "static organs," finally, these have not as yet been shown to be generally possessed by insects.

If we compare the sense functions just mentioned with reference to their direct realm of influnce we shall readily see that none of them is capable of a direct perception of the nest (or rather of the phycho-physiological sensation-complex "nest") from a greater distance than one meter at most. It follows from this that every distance orientation of ants of a greater distance must be indirect, i. e. it must not be produced by a sensory stimulus complex, but in "the sensorium" of the insect, merely as an engram of the goal, by the aid of intermediate direction signals secondarily associated with this engram of the goal. The question here arises whether it is possible to ascribe to such minute creatures as ants such a degree of the capacity for plastic recording and association. Many authors, among them Bethe[4], have, as we know, positively denied the existence of an individual memory in insects and where their experiments have appeared to contradict these preconceived opinions, they have preferred to take refuge in some physiologically inexplicable "unknown power." But before we follow these authorities into the dark domain of scientific mysticism it may be well to inquire whether there may not exist anatomical structures in the central nervous system of the higher insects capable of being regarded as furnishing a morphological foundation for biologically demonstrable plastic nerve activities.

[*Limitations of space oblige us to omit the detailed description which here follows of the brain of the red ant, merely saying that the author appears justified in his contention that the mushroom shaped bodies or Corpora pedunculata may be regarded as a sort of cerebrum.*—EDITOR.]

The marked development just described of the *Corpora pedunculata* is found distinctively only in the phylogentically recent social Hymenoptera (ants, bees, wasps), and in these only in the female and worker castes, which are alone in exhibiting those higher plastic capacities referred to above. In the much more stupid males these organs, as Forel first showed, are always essentially smaller and but slightly convoluted, often, indeed, merely rudimentary. While in the non-social insects they exist at best, if at all, as simple, stratified dorsal protuberances. Thus we look for them in vain in the stupid flies, those proletarians of the insect world. . . . In my opinion, therefore, we may conclude that we have in the *corpora pedunculata* . . . a central association apparatus of high functional value, which may be considered to some extent as an analogue of the cerebrum in vertebrates. . . .

1. *Mass Orientation.*

This is usually, though not always, an orientation along a well defined road, which is usually indicated by a chemical trail, more rarely by actual beaten roads made by the ants. We are chiefly interested here in orientation by an odor trail. . . . this usually exhibits the following phenomena: Along a stretch of 5, 10, or even 100 or more meters, an unbroken column of ants is seen going back and forth between the nest and the goal, the latter usually being a colony of plant lice. Each ant closely follows his leader without varying a finger's breadth from the path and constantly touching the ground with its antennae. That the ants actually follow an odor trail deposited upon the ground is proved by a simple experiment made by the Geneva savant, Ch. Bonnet, more than a hundred years ago: *i. e.* if a finger be drawn squarely across the path the ants on both sides this break in the trail immediately stop and feel anxiously about with their antennae until at last one of them slowly and hesitatingly ventures to cross the obstacle, whereupon the caravan gradually resumes its course. Furthermore, Santschi discovered in 1911, by close observation with a lens, that many ants actually marked the trail by depositing from time to time a minute drop of a secretion which apparently issues from the anal glands. I, myself, have proved the tenacity of this trail odor in the following manner. I allowed ants (*Lasius niger*) to wander through a system of communicating glass tubes, from time to time removing one of the tubes and later replacing it. I found that the odor clung to the removed tubes in almost undiminished strength for 2, 4 or even 8 hours; it was not entirely removed even by blowing through the tube or by washing it for five minutes in cold water. To entirely remove it I had first to wash the tube and then rub it out with raw cotton.

In 1898, Bethe made the remarkable discovery that ants are also able to distinguish between the two directions of the trail by purely olfactory means. In consequence of this discovery the question of orientation by odor has become one of the most difficult and disputed problems of insect psychology.

Bethe led a trail of *Lasius niger* over three narrow boards a, b, c, placed in line between the nest and a colony of lice. When one of these boards, b, Fig. 1, was reversed in position there was always a marked disturbance at each end of the reversed board, although the trail itself was not interrupted. On the other hand a mere exchange of place between the boards caused no disturbance so long as the direction remained the same. Bethe then placed b and c side by side, b in the same direction and c reversed. The natural consequence was an entire interruption at the point where c had formerly been on the part of the ants returning to the nest.

[2] In the *Formica rufa,* one of the kinds which sees best, there are only 600, for example, whereas there are 20,000 in many of the Libellae.

[3] F. Santschi, Obs. et Rem. Crit sur le Machanisme de l'Orientation chez les Fournis. Revue, Suisse, de Zoöl. 1911.—Comment s'orientent les Fourmis. Ibid 1913.—L'oeil composé considéré comme organe d'orientation chez la Fourmi. Rev. Zoöl. Afr. III, 1913.

[4] A. Bethe, Duerfen wir den Ameisen u. Bienen psych. Qual. Zuchreiben?—Arch.f.d. ges. Phys. Bd. 70, 1898.

Those travelling away from the nest upon the board a, on the other hand, all passed from a on to b (which was not reversed), sought the broken trail at the end of b for awhile, and finally wandered on to c and back towards a. Here a new confusion arose, followed by a new passage to b and back again to c. In short the little creatures were "caught in a vicious circle."

From these remarkable results Bethe concluded that the chemical odor particles of the trail possess a polar structure . . . the olfactory perception of this polarization is supposed to release in the ants "a chemo-reflex" which forces them to follow the respective trails from the nest to the colony and vice versa only in the direction of their "polarity."

This polarization hypothesis has found little support in spite of its fascinating simplicity. . . . Wasmann[5] especially refuted it as being unfounded both in theory and in fact. . . . He pointed out that since the ants are constantly travelling in both directions, any polarization of the outgoing path would

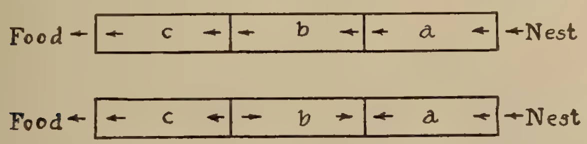


FIG. 1. REVERSING A PART OF THE ANT'S TRAIL.

promptly be counteracted by the reverse polarization of the return trail, unless the two trails were sharply separated from each other, which is never the case.

Wasmann explains the phenomenon by supposing that the ants are able to distinguish between these "odor forms" of their footprints, which naturally point in different directions when going and when coming. If we assume also that in the first direction they probably have a certain nest odor while on the back path they have more of the odor of the colony of lice, we see that both directions of the trail would be clearly indicated by such a combination of two differently directed trail forms with two different kinds of odor. We may find a human analogy by supposing that all the travellers between a city and a village wore shoes which were painted red and which left red footprints behind them, while all the people going in the other direction wore blue painted shoes and left blue footprints.

It must be admitted that this footprint theory seems to explain the phenomenon satisfactorily at first glance; when

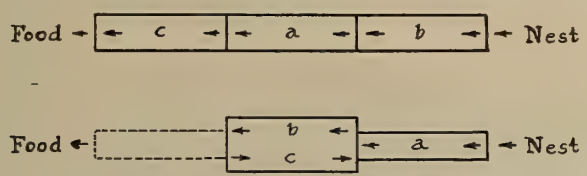


FIG. 2. TRANSPOSING A PART OF THE TRAIL AND TURNING IT BACK ON ITSELF.

we remember on the other hand that an ant has six feet and that often there are thousands of these six-footed tracks mingled in grand confusion on a single trail, it seems to say the least, a very rash and artificial theory.

Forel on the other hand supposed that the chief importance resides not in the trail itself but in the space to the left and to the right of it; it is his idea that through repeated journeyings over the same road the successively encountered objects to the right and the left of the trail gradually caused the ants to acquire a certain sum of associated topo-chemical engrams. In other words they gradually form a map of the path outlined by the objects to right and to left, to the front and to the rear. Naturally, therefore, when part of the road is suddenly whirled around so as to point in reverse directions they are inevitably disoriented, since the odor-forms encountered to left and to right no longer coincide with those recorded in memory.

In my opinion even this brilliant theory is not entirely satisfactory. . . . I therefore determined to study this remarkable phenomenon under variable conditions, so as to be able to analyze it more precisely. My experiments which I have designated as a "Mnemonic Investigation" consisted in causing ants to make journeys now over a path "known" to them (in Forel's sense) and now over an unknown path, so as to observe their manner of determining direction. For this purpose I made use of a colony of the shining black *Lasius fuliginosus* which travel almost exclusively by means of odor trails, dividing them into two parts, A and B. Part A was placed in a temporary container and part B established in an artificial observation nest whose glass exit tubes opened upon a narrow paper bridge 1 meter long (Fig. 3). This bridge ran across the center of a circular experiment table to a small platform, Pl. The central portion of the table together with the portion of the bridge crossing it could be revolved.

In order to study a purely olfactory orientation it was necessary to exclude all other kinds, beginning with optical orientation. To this end I worked inside a dark tent having black walls and ceiling and provided with "bipolar" illumination, *i. e.* having two sources of light placed symmetrically to the right and the left of the table across the axis of the bridge. With this method of illumination it is obvious that an ant travelling from the center of the bridge must receive strictly

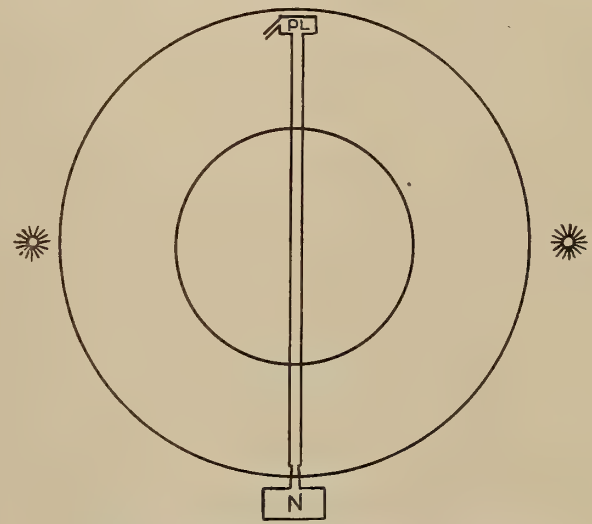


FIG. 3. THE BRIDGE ACROSS THE CIRCULAR TABLE

symmetrical light impressions in both eyes, whose sensory localization remains the same whether it travels towards the nest or in the opposite direction; thus no *relative* direction would be indicated by the source of light.

I placed honey upon the platform and the ants promptly commenced a brisk expedition towards it, which was in full swing a few hours later. I thereupon made the following experiment:

I. By means of a lead pencil I took up ants on the platform which were sated with honey and ready to return to the nest and let them descend in the middle of the bridge, but headed in the wrong direction. Result: All the ants continued for a time in the wrong direction, then stopped, ran back and forth a few times in each direction, and finally set out definitely towards the nest. Thus they seemingly acted according to Forel's hypothesis—as if trying to ascertain the topo-chemical succession.

2. The ants were allowed to descend nearer the nest. The same result, but the right direction more quickly found.

3. Descent in middle, but headed towards nest. Only a few wavered, the others following the right direction hesitatingly at first, but with increasing certainty.

II. I repeated the experiments with ants from A, to which, of course, the bridge was quite unknown. To secure a uni-

[5] Wasmann, die Psych. Faehigk. d.Ameisen. II Aufl.—Schweizerbart'scher Verlag (E. Naegele), Stuttgart, 1909.

form reaction I took only ants already carrying larvae, whose goal was obviously the nest. Result the same, *i. e.* mistaken direction at first, regularly followed by a correction. Hence this olfactory orientation cannot be based upon the existence of a topo-chemical engram-succession, and Wasmann, too, is wrong, since the correct direction was never found until repeated wavering in the two directions had occurred.

III. I next replaced the honey by a quantity of larvae, which the ants at once began to carry to the nest. I was astonished to find that now all the ants which were headed wrong when they descended continued in the false direction without the slightest wavering—in other words, in journeys in which the brood is carried for a long period of time an olfactory indication of direction seems to be entirely lacking. This was even more apparent when I put the larvae on the middle of the bridge instead of on the platform. The ants coming from the nest stopped short when they got to the pile of larvae, ran around it, finally seized one and started home. But fully half went in the wrong direction and arrived at the platform, where they hunted a long time for the door of the nest, and finally turned back towards the nest or else became hopelessly confused. (It must be recalled that all these experiments were conducted in the dark tent with bipolar lighting.) I then placed a "breastwork" of stiff paper (5 mm. high) on one side of the bridge; this was at the left of the ants leaving the nest—at the right of those returning. I left this landmark standing 3 days and then repeated the experiment with the "larvae in the middle." This time not more than a fourth or a fifth of the ants started in the wrong direction, and most of these corrected themselves as soon as the antennae chanced to touch the landmark. These stopped short, struck square across to the other side, stopped again and turned about! This remarkable proceeding was so constantly repeated that all idea of chance is excluded. I then removed the landmark and at once 50 per cent of the insects went wrong, only a few turning about or ever stopping. This evidently proves that *ants can distinguish the topo-chemical impressions upon the left side of the body from those on the right, and that they are capable of associating such constantly localized one-sided impressions with direction*. . . .

I next repeated Bethe's reversing experiment upon my bridge path . . . with the following modifications: At the west end and the platform end of the bridge I placed movable strips of paper equal in width and increasing successively in length. After the travel had continued to pass over these for several hours, I first reversed each strip where it was, and then exchanged two strips, one of which was reversed while the other was not. . . . The results follow:

1. In this case as in the memory experiments the Bethe phenomenon is entirely negative in the "brood expedition," since all of the ants continue to travel without the slightest pause in the same direction, both over the reverse strips and over the interchange strips.

2. On the other hand the phenomenon is entirely positive upon the "food expedition," though with the following important peculiarities:

a. Contrary to Bethe's supposition there was a strong reaction when the nest-strip was exchanged with the platform-strip, but without either being reversed.[6]

b. The reaction increases in proportion with the increasing length of the reverse section of the trail.

c. It is more marked after the exchange of the reversed pieces than after the mere reversal in the same position.

d. It is more intensive at the nest-end than at the food-end.

e. Finally in both places the ants travelling from the nest towards the food constantly react more intensively than the home-returning ants.

In my opinion all these facts can only be explained by the hypothesis *that the odor complex of the ant trail exhibits in the course of its continuity a successive decrease of intensity of certain components, and this apparently, in both directions.* Upon leaving the nest thousands of ants carry with them the nest odor clinging to the feet and antennae and with gradually diminishing intensity, while on the return trip they carry the honey odor in the same manner. Hence there is a strong nest odor near the nest and little or no honey odor, while at the goal the comparative intensity of the two odors is reversed. Thus, if we reverse a section of the trail in the vicinity of the nest the ants arriving there from the nest will suddenly perceive a strong variation of intensity, the longer the reversed section, the greater being this variation. If in spite of this they cross the reversed piece, instead of an increasing honey smell they will detect an increasing nest smell, which is bound to disorient them completely. In the neighborhood of the honey the case will be similar with respect to the odor of the latter, but the honey odor is probably much less intense than the smell of the nest, in which the ants spend a greater part of the day. Furthermore, in the neighborhood of the goal the ants are no longer capable of reacting to the same degree to the smallest variations of the intensity, partly because of the fatigue of the organs of smell and partly because having completed the greater part of the journey they are more confident of the matter. In this manner we can explain the much slighter reaction of the ants in the neighborhood of the goal compared with that at the door of the nest. The memory impulse will be much more effective in the home-coming ants since all of these have already crossed the road on the outgoing journey and are probably, therefore, in the possession of certain actual engrams both of the general topo-chemical constitution of the path and of its length. On this account it is no longer necessary for them to follow the trail with their antennae so slavishly as upon the outgoing journey, and for this reason the more delicate variations of intensity in the constitution of the odor trail may readily escape them.

The matter is essentially different in the case of the "brood expedition." Here the odor of the goal is the odor of the larvae and consequently, because of the transport of the latter, the whole trail will exhale this odor with the same strength as that of the goal. Hence all sections of the path will gradually acquire a completely homogeneous brood-smell . . . which will show no perceptible decrease of intensity either in one direction or the other.

. . . But the olfactory factor is only one component—though a very essential one—of the complex mechanism of orientation. The other factors involved we shall now examine experimentally in the orientation of individual expeditions.

2. *Orientation of Individuals.*

Forel blinded the eyes of red ants by covering them with black varnish and found that the insects thus treated had great trouble in following the trail, constantly wandering to one side. Both Forel[7] and Fabre[8] agree, furthermore, that the armies of the Amazonian ants (*Polyergus rufescens*) when returning from their raiding expeditions are not affected by flooding of the ground in the neighborhood of their dwellings. Miss Fielde[9] noted the same phenomenon when she forced home-coming ants to swim by covering the ground with water. . . . All these authors came to the conclusion that sense of sight, or at any rate a certain degree of visual memory of locality, plays an essential part in orientation, at least with the kinds of ants mentioned.

It has long been known, too, that ants often make single expeditions, sometimes of considerable extent, from the nest, but it was supposed that these single wanderers followed their own trail back. This unfounded supposition was first experimentally disproved by the French psychologist, H. Piéron.[10]

[6]This contradiction to Bethe's results may be explained by the fact that in my experiments the two sections were much farther apart than in Bethe's experiments.

[7]Forel, Fourmis de la Suisse, Geneva 1874.

[8]Fabre, Souv. Entom. II; Paris, Délagrave 1879.

[9]Fielde, Experiments with Ants Induced to Swim. Proc. Acad. Nat. Sciences, Philadelphia, 1903.

[10]Piéron, Du Role du Sens Musc. dans l'Orientation des Fourmis. Bull. Inst. Gén. Psych. 1904.

He removed ants travelling singly homewards from a given point X to a second point X_1, several meters to one side (Fig. 4). The ants thus transported placidly continued the journey, no longer in the direction of the nest, but in a direction exactly parallel to the one originally followed until they had covered an amount of distance which on the original path would have brought them to the nest; they then began to describe confused "concentric curves" as if seeking the nest. In other words they behaved exactly as if they had an internal compass by means of which to find the absolute direction and likewise a pedometer to indicate the distance covered!

This interesting phenomenon led the Algerian engineer, V. Cornetz,[11] to study individual expeditions of ants. He employed the graphic method, marking the course pursued by the insects upon the ground, making precise measurements of this and reproducing it geometrically on a reduced scale, thus obtaining an exact representation of the entire journey. The first thing discovered by him was the fact that the individual travellers do not make use of a scent trail, since the ground in front of them can be thoroughly swept by a broom without causing them the least concern. The expedition is by no means an irregular wandering about, but commonly has a definite main direction, to which the insect returns with great precision after occasional wanderings to one side or the other. *The return trip is never identical with the outgoing trip*, though lying not far away and being in the main parallel. It sometimes occurs, though rarely, that in the course of the journey an ant goes in two or even three different main directions which are usually perpendicular to each other. But on the return journey the diagonal of the triangle or polygon is never taken, but the various main axes are successively followed in the reverse arrangement and for approximately equal distances. When the ant has approached the nest within a certain distance (which varies in length) it usually suddenly abandons the main direction (which is commonly somewhat erroneous) and starts more directly towards the nest; generally, however, it goes a little bit past the mark and this requires a fresh correction. This may be repeated several times so that the ant is really encircling the nest with concentric curves which grow constantly narrower until finally the entrance of the nest is found. It is interesting to note that these corrections always succeed each other in the same direction from the given point (but only from this point). If, for example, an ant which has corrected its path from Y to Z (Fig. 5) is put back to the point Y it returns to Z, but if it is put at any point off the road between Y and Z it will run at random in any other direction.[12]

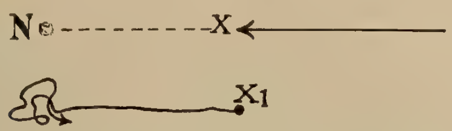


FIG. 4. TRANSFERRING THE ANTS LATERALLY

The parallel course observed by Piéron has been noted by Cornetz in the deepest forest shade or after transportation from the sun to the shade, or vice versa. On the other hand the phenomenon is usually entirely lacking when the transportation is to territory of a different sort, *e. g.* from sandy ground to a meadow, and in my opinion this is a proof that the ants record in the brain the general conformation of the ground observed during their expedition. After a primary transportation away from the nest Cornetz always found the ants to be entirely disoriented, with the exception of a single case which occurred as follows: An ant trail ran squarely across a country road; the nest was situated under a stone at the edge of the sidewalk. When Cornetz sought the place a few days later the trail of ants had all gone in. He picked up a few ants directly at the entrance of the nest and placed them in the middle of the road, a few meters to one side of the previous trail. The ants ran at once back to the curb in a direction exactly parallel to the old trail and then turned to the left exactly as the first trail had done.

FIG. 5. THE ANT CORRECTING ITS COURSE

In spite of the admirable qualities of Cornetz as an observer he fails in interpretation. . . . Thus we find him uttering the following amazing opinion:

"The orientation of individually wandering ants seems to be quite independent in principle of any sort of sensory continuation points in the external world. They seem rather to follow, by means of some unknown absolute inner sense of direction, a course which is established in the sensorium of the insect during the outgoing journey and which enables it to follow such a previously obtained absolute direction, even after the lapse of several days."

This view has recently been attacked and refuted by Dr. Santschi,[13] a myrmecologist, living in Tunis. Santschi believes that every oriented locomotion is necessarily related to some source of stimulus in the outer world. When, therefore, an ant which has been removed from point X to X_1 immediately resumes its former direction there can be only one logical explanation, namely, that the stimulus complex which is tropically effective at X must be present also at X_1 in exactly the same special relation to the sensory perception apparatus of the animal. We have such an omnipresent tropical stimulus coming from the same direction at any given place in a source of light, particularly the light of the sun. Everything which we know in regard to the anatomy and physiology of the eyes of insects appears to Santschi to favor the hypothesis that individually wandering ants orient themselves by light.

We have seen that facetted eyes are chiefly adapted for seeing motions, *i. e.* relative alterations of locality in the retinal image. If this is correct they appear to be also adapted to the localization (during the movement of the body in a straight line) of large distant stable objects or distant direct sources of light in an uncommonly exact manner. . . . Thus in order to keep to a definite straight direction the animal only needs to keep the image of the sun in certain facets. And furthermore, if it so places itself upon the return journey that the image of the sun constantly strikes the diametrically opposite corresponding facets of the other eye, it is clear that the return path will be parallel to the initial path and will, therefore, lead pretty nearly to the starting point. From these premises Santschi formulated his brilliant theory as follows:

The facetted eyes of ants act in a measure as light compasses, thus enabling them to pursue a given direction in a straight line and also to return with certainty to the starting point. The method of operation consists of an exact sensory localization of the source of light during the outgoing journey and also during the return journey by means of a sensory reversion of the said localzed light impression upon the diametrically symmetrical sensory surfaces. The parallel journey observed by Piéron is nothing more, therefore, than a virtual orientation towards the source of light. Among the numerous experimental facts by which Santschi supports this theory, I will quote only the mirror experiments.[14]

In the path of individual home-going ants Santschi shaded the terrain by a large screen and then projected the image of the sun to the other side by means of a large mirror. The result was always the same—the insect immediately turned about and ran in the opposite direction, *i. e.* away from the

[11] Cornetz Trajets de Fourmis et Retours au Nid. Nem. de l'Institute gén. Psych. 1910.

[12] Cornetz, La Connaissance du Nonde environnant son, gite pour une fourmi d'espéce supérieure. Rev. d. Idée, 1912.

[13] Santschi, Comment l'Orient les Fourmis. Rev. Suisse de Zoöl. 21, 1913.

[14] Revue Suisse de Zoöl. 19, 1911.

nest as long as the false sun was shining. If the mirror was so turned that the false projection of the sun was at right angles the ant followed a corresponding direction at right angles to its former one. . . .

But Santschi was not the first to prove the orientation of ants by light, though he gave it a more exact physiological basis. More than thirty years ago Lubbock[15] showed that ants immediately reversed their path when the source of light is reversed. . . .

I have obtained similar results by other methods. . . . Over an ant which was running across a playground covered with sand in a direction almost exactly opposite the sun I placed a small round cover. I kept the ant captive exactly two hours; when I removed the cover at five o'clock the ant was resting motionless in the center of the little cover. It turned itself slowly about and travelled again almost in a straight line over the sand in the direction of the flower bed at whose edge its nest was situated. But the line of the return path deviated from the outgoing curve by 30° to the right, i. e. by exactly as many degrees of an arc as the sun had travelled to the left in the firmament during the two hours which had elapsed (Fig. 6). I repeated the experiment varying the time. In every case the angle of deviation of the return curve corresponded to the solar angle concerned, with only a very slight amount of error. It is not surprising that the ants should not have taken into account the time of their imprisonment and the fact that the sun had travelled farther across the firmament in the meantime—on the contrary, it would

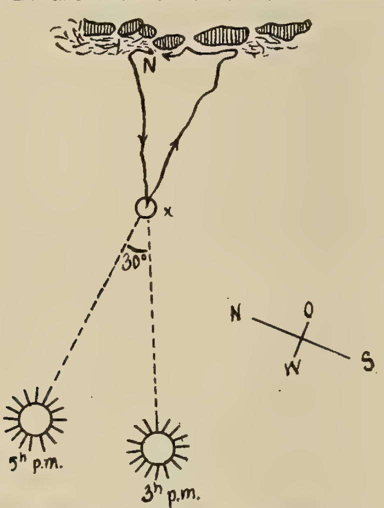


FIG. 6. HOW THE DIRECTION OF THE SUN AFFECTS THE COURSE OF THE ANT

be quite wonderful if they were capable of arriving at this logical conclusion.

On the other hand this fixation experiment failed almost entirely in precisely those varieties of the species *Formica* which are provided with the best eyes and which also stand the highest phsychologically. These ants resumed their former direction after the fixation without perceptible deviations. Many other things indicate also that these ants usually orient themselves on their individual journeys in a much freer manner than is compatible with the light compass theory. I rarely succeeded with these in obtaining a typical parallel journey, especially when the lateral removal was only a few meters in extent, since in this case the ants not seldom cancelled the lateral deviation by a corresponding cross course. In short the impression was obtained that the distance orientation was here largely secured by *differentiated visual complexes*, possibly by the more or less indistinct perception of certain large objects at a distance, such as trees and houses, with whose position that of the nest was associated. This hypothesis is favored by the results of certain other experiments which I undertook with the *Formica sanguinea*, originally with the purpose of studying the influence of kinesthetic angle-registration. I drove certain ants away from the nest forcing them to go to the left upon the above mentioned area of sand and obliging them by my hands to follow a patch curved in a certain definite manner which I had previously drawn in the sand. To my surprise after accomplishing such a "forced journey" the ants always returned at once and in the most direct line to the nest, although the point where I let them go free was often quite far from the nest—20 to 34 meters, and the return journey was made after a right-angled forced journey, not by means of successive reversions of the two legs of the way, but in a diagonal direction, *i. e.* with a direct completion of the polygon (Fig. 7). I then forced the ant to follow large curves, or, in other cases, very complicated many-angled curves including many opposite directions; in the first cases the return was made promptly along the secant and in the second cases along the approximate resultant of the original curve, *i. e.* pretty directly in the direction of the nest. When the ants were transported directly to the end of the curve without having previously followed it, they appeared to be completely disoriented—a proof that the direction engram concerned was actually obtained during the forced journey. I then blinded several ants and took them over a simple forced journey consisting of two axes; they were absolutely incapable of making the return journey, only a single insect making a laborious attempt to go back over the second leg of the way. Hence the diagonal path taken cannot be based upon a complicated association of kinetic angular engrams. Finally I made an ant take a forced journey having two axes and of very great length, extending far beyond the sandy area. The result was that the insect did not at first

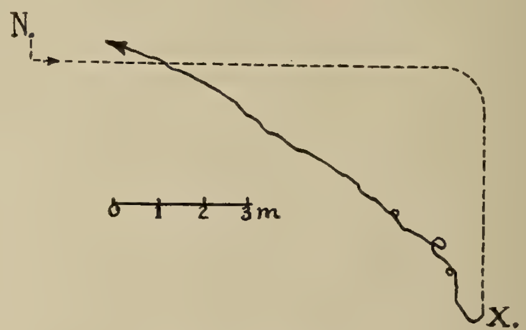


FIG. 7. RETURNING IN A DIAGONAL COURSE AFTER A FORCED DIGRESSION

take the diagonal, but reversed the second leg of the journey, but suddenly corrected its course, on reaching the sandy area, in the direction of the nest.

The question arises: Do ants possess an individual memory of locality, based upon successive associated engrams as has been proved to be true of bees? . . . Cornetz has denied the existence of such a genuine memory of locality, upon the ground that after being carried away from the nest ants are always completely disoriented. On the other hand I can offer in the support of this theory a whole series of observations of *Formica* in which these ants after being carried to a distance of 30 m. almost immediately reoriented themselves upon the shortest path towards the nest. It is true that I did not place my ants at some chance place selected at random, but at a location which had previously been frequently visited by the colony in question, so that it was to be expected that numerous ants would possess individual engrams of it. Naturally, however, I did not conduct the experiments until these visits had been entirely interrupted for some weeks and I also took every precaution to exclude every possibility of the presence of any odor trail to guide the insects.

I maintain, therefore, that we must attribute to these creatures a genuine—even if limited—memory of locality, based upon successive associated engrams of direction. . . .

But we have not yet exhausted all the means of orientation of which ants may possibly avail themselves, not at all! We still have an important group to be considered, *i. e.* the

[15] Ants, Bees, and Wasps, London, 1881.

kinesthetic signs of direction. . . . It has long been a disputed question as to whether insects are capable of feeling the force of gravity, and this has generally been denied in view of the extremely small weight of their bodies and the comparatively enormous muscular power which they are capable of exerting. It is my good fortune, however, to be able to offer proof that ants are not only capable of perceiving moderate elevations of the terrain by purely kinesthetic means, but that they are also capable in case of necessity, *i. e.* when all other signs of direction are excluded, of orienting themselves merely by this single, meagre kinesthetic engram.

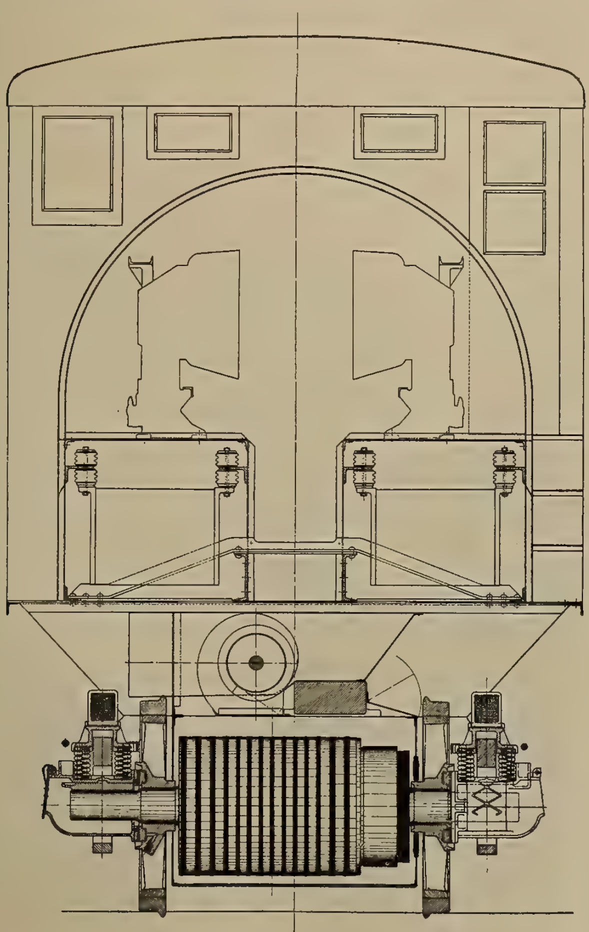
I proceeded as follows: To the edge of my large experimental table I attached an artificial nest containing a small colony of *F. rufa.* The exit tubes of the nest gave upon the top of the table. This table is so constructed that its top can be revolved in every plane of space, and all its axes of movement are exactly centered. In these experiments the table top was inclined at an angle of 20° to begin with in such a manner that the entrance to the nest was at the deepest position. The insects had to crawl upwards to reach the honey which was in a round bowl at the center of the table. Since the experiment was conducted in the dark tent with bipolar lighting described above orientation by light was excluded. I waited till an ant was seated at the feast of honey and then noiselessly changed the slope on the table top to the opposite direction, so that the nest was now above. Having finished his feast the insect started home, but was met by an unexpected puzzle! In all cases the ant first spent considerable time running back and forth undecidedly in both directions for a few centimeters each way, always returning to the honey. (It is interesting to note here the difference between these ants and the *Lasius* of the bridge experiment, which usually ran straight ahead in one direction—the *Formica* seemed on the other hand to be obviously conscious of a dilemma.) Finally, however, in every case the insect decided on a direction, and all of them *ran downwards without exception,* almost exactly to the deepest point, where they described narrowly limited curves for a long time, quite as if they were actually seeking the disappeared entrance to the nest!

Thus they had actually accomplished a virtual orientation by means of gravity! I must forego the citing of many interesting data bearing upon this complex theme. I trust, however, that I have convinced my audience that the distance orientation of ants is an uncommonly complicated phycho-physiological process. . . . Thus comparative psychology has here become an exact science—the comparative physiology of the individual Mnemo.

A Gearless Electric Locomotive

Details of the 3,000-Volt D.-C. Locomotive of the Chicago, Milwaukee and St. Paul Railway

IN the SCIENTIFIC AMERICAN of December 6, 1919, there appeared a narticle on an interesting "tug of war" between a giant electric locomotive and two steam locomotives. Rather it was a push of war for had a pulling test been staged the draw bars of the locomotives could not have stood the strain. In the test the electric locomotive came out victorious even though the steam locomotives were given a head start so as to enable them to attain their maximum horsepower. When the current was turned on the electric unit gradually slowed down the steam locomotives and then pushed them backward with accelerating velocity.



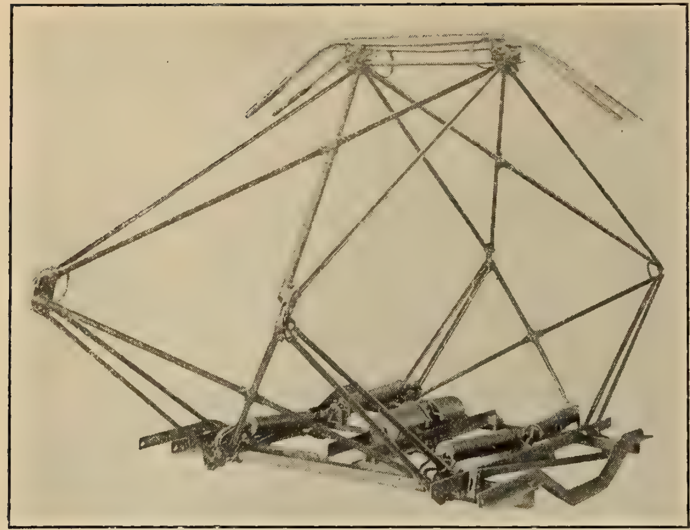
END ELEVATION OF THE GEARLESS LOCOMOTIVE

The big electric locomotive was one of a set of 3,000 volt direct current locomotives that are now being placed for passenger service on the Othello-Seattle-Tacoma electric zone of the Chicago, Milwaukee & St. Paul Railway.

The original electrification from Harlowton to Avery, 440 miles, has now been operating for a number of years under the extremely bad weather conditions of the Rockies and Bitter Root Mountains and, as a result of its unqualified success, the same system will now be used to meet the severe grades and snow conditions of the Cascade Range. The entire equipment for the original electrification was manufactured by the General Electric Company including substations and locomotives. The motive power consisted of 42 locomotives for freight and passenger service and four switchers. Of this original equipment, the freight and passenger locomotives were practically the same and differed from each other only in the gear ratio between motors and driving axles.

The new locomotives are an entirely different design, built distinctively for passenger service and possess some very interesting mechanical and electrical features. They will be used on the new Cascade electrification strictly for passenger service and the present passenger engines will be adapted for freight service by changing the gear ratio. The locomotives are of the bi-polar gearless type, with motor armatures mounted directly on the driving axles. In this fundamental feature, they follow the design of the gearless locomotives in use on the New York Terminal of the New York Central Railroad, which have given remarkable operating results during the past ten years. The chief advantage of this method of construction is the great simplicity of mechanical design which eliminates all gears, armature and suspension bearings, jack-shafts, side-rods or other transmitting devices. The remarkably low cost of maintenance of the New York Central locomotives over the entire period is attributed largely to the gearless type of construction.

The new Chicago, Milwaukee & St. Paul locomotives weigh 265 tons with 229 tons on drivers. They have fourteen axles,



TYPE OF PANTAGRAPH USED ON THE NEW GEARLESS LOCOMOTIVE

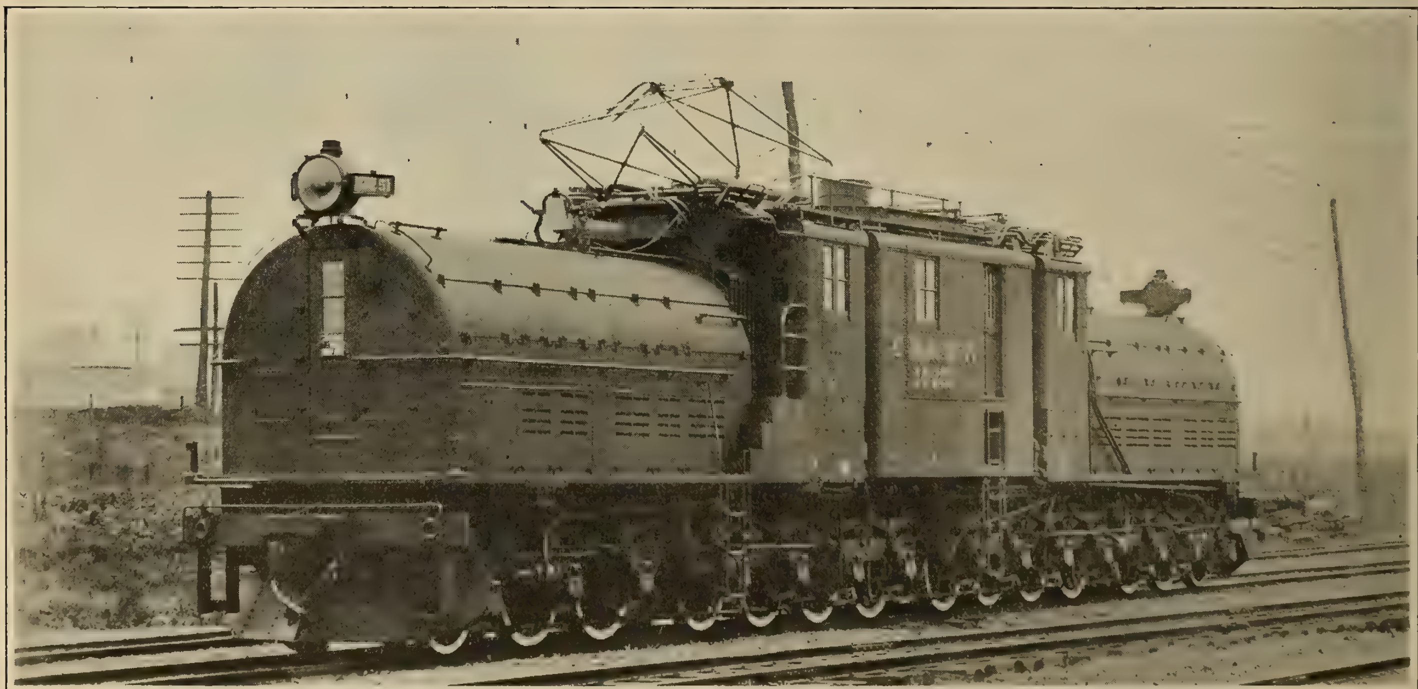
twelve of which are driving and two guiding axles. The weight of the armature and wheels is the only dead weight on the track and this is approximately 9,500 pounds per axle. The total weight on drivers (458,000 pounds) is 86 per cent of the weight of the locomotive but, being distributed among twelve axles, results in a weight of only 38,166 pounds per axle.

One of the most interesting and important features of the locomotive is the design of the leading and trailing trucks and the method of suspension of the cab weight upon them. The successive trucks are coupled together in such a way as to deadbeat or break up any lateral oscillations which may be caused by inequalities of the track. The weight of the main cab is so supported on the front and rear trucks that any lateral thrust or kick of the leading or trailing wheel against the track is cushioned by the movement of the main cab, which increases the weight bearing down on the wheels at the point where the thrust occurs, and automatically reacts to prevent any distortion of the track. The result of this design is such as to give riding qualities at high speeds which have probably never been attained before in a double-ended locomotive. Exhaustive tests on the General Electric Company's test tracks at Erie, Pa., have demonstrated the remarkable riding qualities of the new locomotive at speeds as high as 65 miles per hour which is the limit of speed on the length of test track available. These tests also indicate that the locomotive will operate at much higher speeds with equal success.

The locomotive is designed for handling in normal service a 12-car train weighing 960 tons trailing against a grade of 2 per cent at 25 m.p.h. This performance requires 56,500 pounds tractive effort which is equivalent to a coefficient of adhesion of 12.3 per cent of the weight upon the driving axles. The wide margin thus provided between the operating tractive coefficient and the slipping point of the wheels, as well as the ample capacity of the motors, will allow this locomotive to haul trains with as many as fourteen cars in emergencies. For continuous operation, the locomotive is designed to operate at 42,000 pounds tractive effort at a speed of 27 m.p.h.

The total weight supported on driving axles is practically the same as that on the present geared passenger locomotives, weighing a total of 300 tons. The table below gives the principal dimensions, weights and capacity of the gearless locomotive:

Length inside knuckles	76 ft. 0 in.
Length over cab	68 ft. 0 in.
Total wheel base	67 ft. 0 in.
Rigid wheel base	13 ft. 11 in.
Diameter driving wheels	44 in.
Diameter guiding wheels	36 in.
Weight electrical equipment	235,000 lb.
Weight mechanical equipment	295,000 lb.
Weight complete locomotive	530,000 lb.
Weight on drivers	458,000 lb.
Weight on guiding axle	36,000 lb.
Weight on each driving axle	38,166 lb.
Number of motors	12
One hour rating	3240 h.p.
Continuous rating	2760 h.p.
Tractive effort—1 hour rating	46,000 lb.
Tractive effort—continuous rating	42,000 lb.
Tractive effort—2 per cent ruling grade with 960-ton train	56,500 lb.
Coefficient of adhesion ruling grade	12.3 per cent
Starting tractive effort—25 per cent coefficient of adhesion	115,000 lb.
Rate of acceleration starting 2 per cent ruling grade	0.48 m.p.h.p.s.



THE 3000-VOLT D.-C. GEARLESS PASSENGER LOCOMOTIVE, WEIGHT 265 TONS

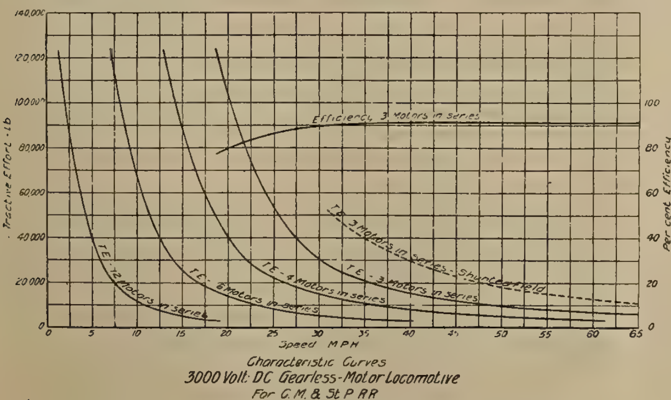
A WEST-BOUND FREIGHT TRAIN, NEAR GRACE, ON A 2% GRADE—55 CARS, WEIGHT 1,450 TONS

The control equipment for the new locomotive is similar in most respects to that used on the original locomotives which have now been operating nearly four years. Modifications were, of course, necessary to comply with the different arrangement of motors. Advantage is taken of a new scheme of connections by means of which four of the main locomotive motors are utilized to furnish exciting current during regeneration, thus reducing the size of the motor-generator set used for control, accessories and train lighting. An appreciable reduction in the weight of control equipment is obtained, at the same time providing for effective regenerative electric braking on the down grades. The motor-generator set furnishes control current for operating the contractors and for charging an 80-volt storage battery which supplies lights and power for the accessory apparatus. The battery is, in general, similar to those used on the passenger coaches. The master controller is constructed in three sections arranged for both motoring and regenerating, all of the cylinders being suitably interlocked to prevent incorrect manipulation.

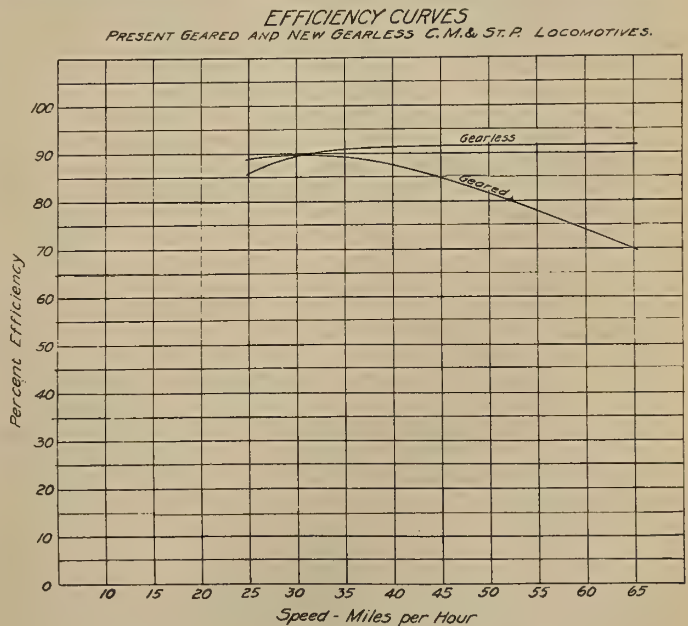
The motor is bipolar, two fields being supported upon the truck springs with full freedom for vertical play of the armature between the pole faces. On page 57 is shown an outline of the locomotive and one of the motors in section indicating the location of the armatures and the magnetic section. For full speed operation, the twelve motors are connected three in series with 1,000 volts per commutator. Control connections are also provided for operating four, six or twelve motors in series. Additional speed variation is obtained by tapping the motor fields in all combinations. Cooling air for each pair of motors is supplied by a small motor-driven blower. This arrangement avoids the heavy duct losses encountered with a single large blower.

As may be seen from the curves herewith, the gearless locomotive shows a much better efficiency at high speeds than the geared type owing to the elimination of the gear drive. In passenger service, where there are long stretches of level track and stopping points are comparatively few, a much higher efficiency is obtained in all-day service. These curves show an efficiency at 50 miles per hour approximately 10 per cent higher than the geared type of locomotive.

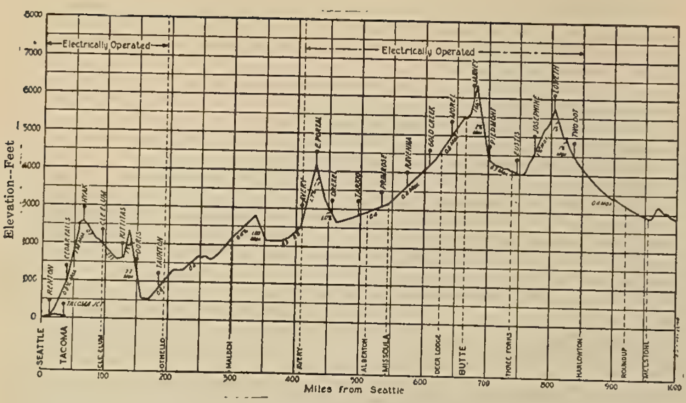
The 3,000-volt contactors and grid resistors are mounted in the curved end cab at each end of the locomotive. In one of these cabs there is also located the 3,000-volt d-c. air compressor and storage battery. In the other is located a small motor-



CHARACTERISTIC CURVES OF THE GEARLESS LOCOMOTIVES



EFFICIENCY CURVES ON GEARED AND GEARLESS LOCOMOTIVES



PROFILE OF THE ELECTRIFIED DIVISION OF THE CHICAGO MILWAUKEE AND ST. PAUL RY. FROM HARLOWTON TO THE COAST

generator set and the high speed circuit breaker. The operating cabs contain the master controller, indicating instruments, and a small air compressor (in No. 2 cab) operated from the battery circuit with sufficient capacity for raising the pantograph when first putting the locomotive in operation. Near the controller are the usual air brake handles for standard braking equipment.

The center cab is occupied by the oil-fired steam boiler for heating passenger trains with accessories including tanks for oil and water, circulating pumps and a motor-driven blower for furnishing forced draft. A slider pantograph, similar in construction to those now in use, is mounted on each of the operating cabs. This pantograph has two sliding contacts, giving a total of four points per slider with the double trolley. The pantograph and flexible twin trolley construction enable the locomotives to collect currents as high as 2,000 amperes at speeds up to 60 miles per hour without noticeable arcing at the contact points. The second pantograph is held in reserve as a spare. Sand boxes, with pipes leading to each pair of driving wheels, are located directly beneath the pantograph outside the operating cab.

The diagram above gives a profile from Seattle to a point about 1,000 miles east, including the Cascade electrification, the Harlowton-Avery electrification and the intervening 220 miles. The new locomotives will operate over the section between Othello, Seattle and Tacoma, including 17 miles of 2.2 per cent grade from the Columbia River west and 19 miles of 1.7 per cent grade between Cedar Falls and the summit of the Cascades. The traffic over this division consists of the heavy main line transcontinental passenger trains "Olympian" and "Columbian," carrying from 8 to 12 steel passenger coaches which will be handled over the maximum grades without helpers. Freight pushers are already in operation on the 2.2 per cent grade, using two of the locomotives from the original electrification. It is expected that electrical operation during the present winter will assist in overcoming many of the delays which are commonly met with during winter operation in this district.

CONCRETE FUEL OIL RESERVOIRS.*

By H. B. Andrews.

Until recently steel containers have been used generally for fuel oil. Concrete had not been considered as a suitable material due to lack of evidence and knowledge of its possibilities. But the practical elimination of steel plates during the war forced the use of a substitute, and reinforced concrete has proved to be satisfactory in many ways, if intelligently handled.

For example: It is necessary to install most fuel oil reservoirs underground, but steel tanks rust if not protected. Concrete can be designed better to resist exterior stresses, as hydrostatic or earth pressures. It has the dead weight better to resist upward hydrostatic pressure in soils which often are filled with water. It does not attract lightning like steel, nor if properly constructed is it affected by electrolysis. It is a non-conductor of heat and cold, thus retarding evaporation of oil in summer, and also retarding the lowering of temperature of the oil in winter—an advantage in pumping. In case of a conflagration the oil is much safer in a concrete container than in steel.

But as previously stated, oil reservoirs of concrete must be designed correctly, the concrete proportioned correctly and mixed and placed correctly in order to get satisfactory results. And by satisfactory results it is meant that there shall be no leakage or seepage when built or thereafter to cause fire hazards or financial loss.

When these necessities have been provided for, reinforced concrete reservoirs will contain fuel oil of a consistency up to 40° B., and practically all fuel oils are below this, the Mexican oils having a specific gravity as low as 16° B. For the lighter oils, including kerosene, gasoline or benzine, some provision should be made for a lining of special material, and the writer understands that the U. S. Shipping Board has been making some extensive experiments along this line.

The design and the location of a fuel oil reservoir may be considered from various standpoints.

(1) Location. The reservoir should be located a safe distance from inflammable structures as far as possible consistent with pumping requirements, covered with at least 16 inches of earth, if near buildings, to decrease fire hazards and also to minimize oil evaporation. If distant from buildings it should be at least half underground, and if possible, the excavated material should be used in banking up around it.

(2) Size. The reservoir should be limited in size for two reasons: First, the necessity of not exceeding a day's working limit in operation of pouring concrete so that joints between operations may be eliminated and secondly, so that in case of an accident or fire in any reservoir, that too much oil in storage will not be involved. This size limit should not be over 300,000 gallons under most conditions, and the majority of contractors have not the facilities to construct properly a reservoir of this capacity.

(3) Shape. The reservoir should be circular in shape, the better and more directly to take care of involved stresses and to avert danger of tensile or temperature cracks.

(4) It should be so proportioned and designed as to limit the number of pouring operations of concrete, so as to avoid joints between these operations.

(5) Care should be taken to provide for all exterior stresses, such as hydrostatic pressure from ground water, earth pressure on walls, and roof if reservoir is buried, and also to avoid as far as possible concentration of loads on walls or footings. Where joints are absolutely necessary to so protect these joints that there will be no leakage through them.

Regarding hydrostatic pressure, while engineers have found from tests that this pressure in soils is only about 50 per cent of the full head of water, it is not safe to design for stresses less than the full head, as any deflection in the concrete admitting a film of water between the earth and the concrete will produce the full hydrostatic pressure.

(6) To so design the reservoir, piping and vents as to comply with municipal regulations and insurance requirements.

(7) To protect temporarily or permanently concrete surfaces so that oil will not come into immediate contact with them if concrete is less than six weeks old.

(8) To so design the false work for holding concrete temporarily in place that it will not fail or be distorted while placing concrete. It is especially necessary to provide for the firm holding of wall forms, as the pressure of several feet of concrete poured quickly as a monolith, is intense, and any give of the forms after the concrete has obtained its initial set breaks up the crystals already formed, allows ex-

*From *Oil News*.

pansion of the concrete mass, with resultant porosity and loss of strength.

(9) To design the concrete so that it will resist all exterior stresses to which it is subjected and so that it will be oil-proof. And one of the principal features of this design is to make the walls of circular reservoirs in tension, sufficiently thick so that the ultimate strength of the concrete in tension will not be exceeded. It is not meant, of course, to leave out the steel reinforcement so that the stress will theoretically be borne by the concrete, but, nevertheless it will actually be borne by it unless some unforeseen weakening of the concrete should throw it upon the steel.

An extended investigation by the writer on high circular concrete standpipes for water showed that if the concrete in the wall was stressed beyond its elastic limit or ultimate strength, which is practically identical, vertical hair cracks will appear of sufficient width to admit water into the body of the concrete.

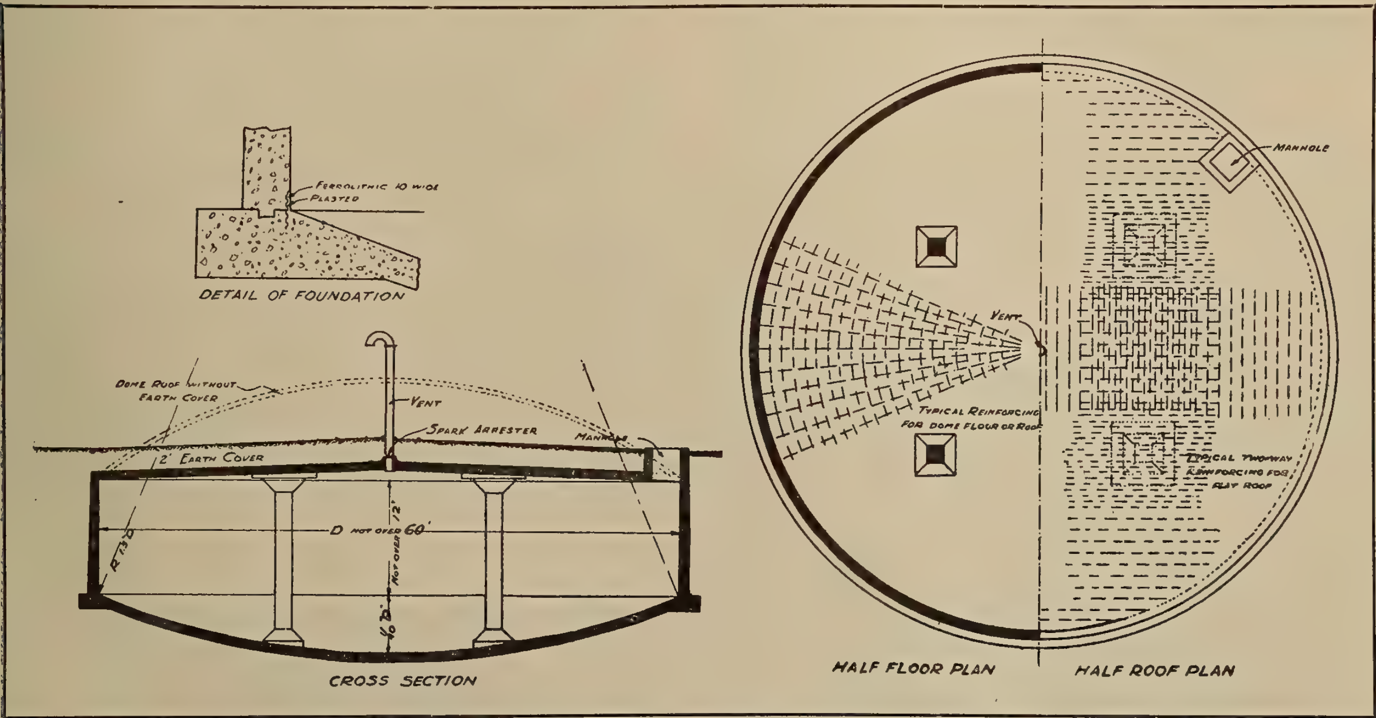
the Joint Committee on Concrete, Plain and Reinforced, should be followed.

All reinforcing rods in concrete exposed to oil should be of a deformed section for better bonding value.

COMPETENT ENGINEERS ARE NECESSARY.

To carry out these requirements necessitates the employment of competent engineers, experienced in the work, to make the design and specifications and to superintend construction.

The concrete should be no leaner than a mix composed of 1 part of cement, 1½ parts of sand and 3 parts broken stone or gravel. To this mix should be added a "densifier." Hydrated lime has been found economical and satisfactory for this purpose, using 10 pounds of dry lime to each bag of cement. The stone must be hard and clean, trap rock, granite or gravel being the best material. The sand must be free from any deleterious matter, and should be well graded. Cement should be of an established quality.



PLANS OF A TYPICAL REINFORCED CONCRETE FUEL OIL RESERVOIR

This ultimate tensile strength in a 1:1½:3 concrete from tests made for the writer at the Watertown Arsenal was 203 pounds per square inch. Where the concrete is in large sectional areas and reinforced, this tensile strength probably will be somewhat higher.

If a stress not exceeding 150 pounds per square inch is allowed in tension there will be no danger of these vertical cracks appearing.

(10) To design the reinforcement so that it will take care of all interior and exterior stresses and with fittings to hold it rigidly in place while concrete is being poured. Steel in tension in walls should not be stressed over 10,000 pounds per square inch to conform with insurance companies' requirements.

Personally, the writer does not think that it is necessary to figure the stress as low as this, under usual conditions, having satisfactorily constructed many reservoirs using a stress of 14,000 pounds, but of course, the lower stress is an additional safeguard against inferior workmanship by inexperienced contractors and against any decrease in bond strength due to oil penetration of concrete. It is probably unwise to depart radically from insurance companies' recommendations.

For other parts of the reservoir the recommendations of

The concrete should be deposited continuously in concentric layers not over 12 inches deep in any one place.

No break in time of over 30 minutes is permissible in depositing concrete during any one operation, and if any delay occurs, the previous surface must be chopped up thoroughly with spades before the next layer of concrete is deposited.

The different operations in pouring are:

1. The pouring of floor and footings.
2. The pouring of entire wall.
3. The pouring of roof.

In small reservoirs the wall forms may be supported so that the footings, floor and wall may be poured in one continuous operation.

An approved joint or dam must be made between the floor and the wall.

When the materials are obtained they should be mixed by a plant of sufficient size and power to carry out each separate pre-arranged operation without danger of delay during the process.

The materials should be mixed at least 2 minutes in the mixer, using just enough water to obtain a plastic mix without excess water coming to the surface after concrete is deposited, and a measuring tank should be used so that the amount of water may be kept uniform.

A Vacuum Pan for Laboratory and Experimental Use

Directions for the Construction of the Apparatus

By F. Alex. McDermott, Mellon Institute, Pittsburgh, Pa.

IT frequently happens in experimental work that it is desirable to have some small apparatus for the purpose of evaporation of a liquid in a vacuum, which will have characteristics rather nearer those of the large commercial machines than can be obtained with a simple round bottom flask. The apparatus which is here described was designed to meet this need, and has proven very satisfactory for a considerable number of purposes. In copper and brass it can be made easily by anyone who can do soldering and has the use of a small screw-cutting lathe, or a simple lathe and a pipe-threading device.

The original apparatus, shown in the photograph (Fig. 4) was constructed of aluminum, for use on acid food-products

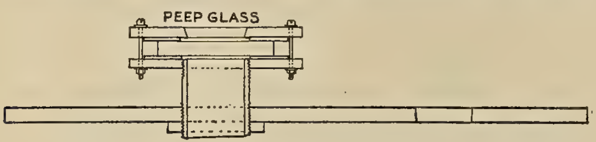


FIG. 1. SECTION OF LID SHOWING MOUNTING OF PEEP GLASS

such as fruit juices, where copper or iron could not be used on account of the attack on the metal and consequent deterioration of the flavor of the product. In this case, the body of the pan consisted of a cylinder of aluminum, 7½ inches in internal diameter, with walls 3/16 inch thick, closed at one end by a flat bottom ¼ inch thick, and provided at the top with a flange 3/16 inch thick and 1 inch wide, making the total diameter of the top 10 inches. The construction of an aluminum body for such a vacuum pan, owing to the difficulties in the way of working aluminum with the facilities ordinarily available to the amateur, is best done by those who are constantly working with the metal, and in the case of the original apparatus, was done by an outside untensils factory. The method employed appears to have been as follows: a sheet of metal 3/16 inch thick was bent into the form of a cylinder 8 inches in outside diameter; a piece of metal ¼ inch thick was then spun out to form the bottom and a portion of the side, of the same outside diameter as the cylinder; the seam in the cylinder was then welded together, and the spun out bottom welded on, making a solid, one-piece body, the flange being welded on around the open end. The body of the original aluminum pan is 13 inches deep inside, of which depth, the welded cylinder represents about 10½ inches.

For the amateur, copper construction is much easier, and for use with this pan a small copper body was also constructed as follows: A piece of sheet copper, tinned on one side, and about 1/32 inch thick, was cut 6⅜ inches wide and 25¼ inches long; this was rolled into a cylinder eight inches in diameter, tinned side in, and a crimped joint made at the seam; a circular disk of the same copper, 6¼ inches in diameter was then taken, and one-eighth inch of the edge hammered over to form a flange at a right angle all the way round, the tinning being on the side opposite to that over which the edge had been turned. This disk was then slipped into one end of the copper cylinder, as shown in the sketch (Fig. 2) until somewhat more than one-eight of an inch of the cylinder was exposed below the end of the turned-over edge of the disk; this projecting edge of the cylinder was then turned in over the edge of the disk, and crimped down firmly in place. Of course a dished head of thicker metal, with a short cylindrical extension to slip over the cylinder, could be used in place of the flat head to some advantage. In either case the upper end of cylinder is fitted with a brass ring ⅛ inch thick, one inch wide, and 10 inches in outside diameter, which fits snugly around the cylinder; all joints are then liberally soldered. If it is desired that only the tinned surface be exposed to the liquid to be treated in the pan, this soldering should all be done on the outside of the pan; if the pan is to be silver plated inside, plain copper may be used, and the soldering put on the inside. If a pan more than 6 inches deep is desired it will be necessary to use much heavier copper, or to reinforce the body by soldering in a ring of ⅛ inch brass, fitting just inside of the cylinder, at each four to five inches of the total height—i. e., one such ring in a pan 10 inches deep, two in pan 15 inches deep, etc.

In the pan as constructed all heating arrangements, inlets and outlets, etc., are provided through the cover. This was done to obviate the necessity for holes through the body, which might be difficult to make tight. The cover thus becomes an important piece of the apparatus. It consists of a disk of the metal used (aluminum for the aluminum pan, brass, plated if desired, for the copper pan, etc.), ⅛ or 3/16 inch thick, and 10 inches in diameter. In this cover are drilled seven holes, as shown in the drawing (Fig. 3); four of these are ¾ inch in diameter, tapering very slightly to the under side of the disk, and are to receive rubber stoppers bearing the steam inlet and outlet tubes for the heating coil, a thermometer, and a separatory funnel or other device for admitting liquid to the interior of the pan. The other three holes are threaded to receive one inch standard pipe, and are to provide for the vapor outlet and peep glasses. In the original pan all of the latter were made up from sheet aluminum of standard thickness, or of standard pipe fittings, which may

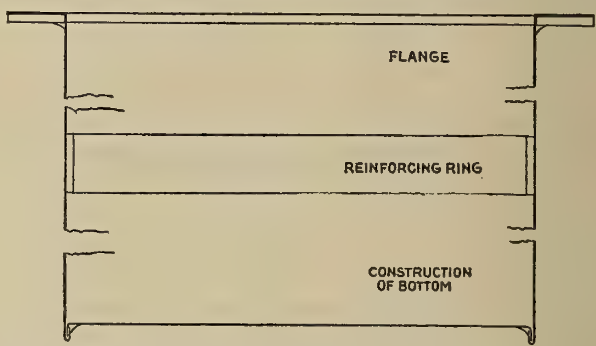


FIG. 2. SECTION OF BODY SHOWING ASSEMBLY OF DISK AND CYLINDER

be obtained in aluminum. The peep glasses consisted of a circle of plate glass two inches in diameter clamped against washers of 1/16 inch red rubber packing, ½ inch wide, between circles of the metal used, 3/16 inch thick and 3¾ inch diameter; using brass, these circles could be made somewhat narrower, 3½ inches diameter, at least. The central hole in each was bored one inch in diameter, and the upper circle of the peep-glass was reamed out to a taper to 1¼ inches at the top; the hole in the lower circle being tapped for one inch standard pipe thread. The two pieces, with the included washers and glass, are held together by six bolts with nuts and washers, spaced evenly, and with centers ½ inch from the edge of the circle.

The peep glasses (Fig. 1) are mounted on short lengths of standard one-inch pipe, projecting about ⅜ inch on the under side of the cover, and a hexagonal nut, made from a piece of sheet aluminum or other metal used, is screwed up tightly against the cover on this projecting nipple to reduce the possibility of leakage in of air when exhausted. A simi-

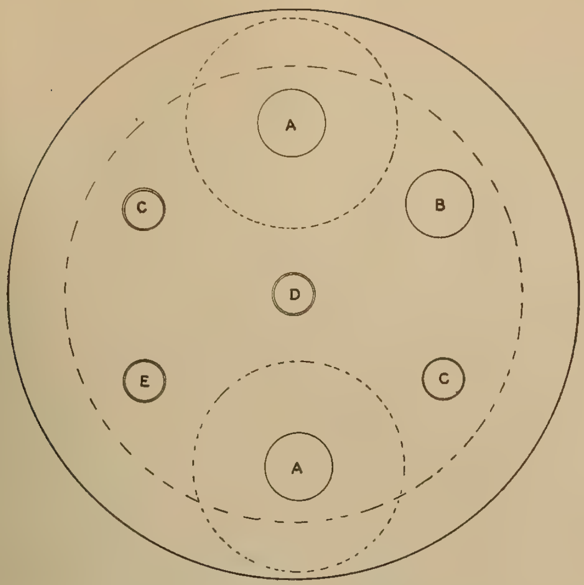


FIG. 3. HOLES IN HE COVER OF THE VACUUM PAN

lar lock nut is used on the vapor outlet pipe. By placing a shaded electric light over one of these peep glasses, the condition of the contents of the pan may readily be observed through the other.

The vapor outlet is arranged to have ample cross section, and to provide for connection by means of a rubber stopper to a surface condenser; a vacuum break is also provided in this connection in the original apparatus. The vapor outlet consists of a vertical piece of one-inch pipe, about 6 inches long, bearing at its upper end a standard T, with the side outlet facing outward at right angles to the axis of the body of the pan. Into the upper, open end of this T is conencted the vacuum break—an ordinary stop-cock, connected by standard threaded pieces, and preferably so arranged that any vapor which may condense in it when closed will not run back into the contents of the pan. To the side outlet is connected a short piece of the same pipe, then a 45° elbow, and then another piece of the same pipe, the free end of which is slightly tapered to take a large rubber stopper. A mercury or dial vacuum gage may be connected at the vacuum break.

As a condenser the original apparatus is used in connection with a multitubular condenser consisting of seven 3/16-inch copper tubes, 15 inches long, surrounded by a water jacket; this condenser has given very good results with this pan. Single tube condensers of either metal or glass are usually insufficient to condense more than a portion of the vapor of the liquid boiling under vacuum. The outgoing end of the condenser is connected by means of a rubber stopper into a 2- or 4-liter filter flask in which the condensate collects. Direct connection to a wet type vacuum pump, or to water jet vacuum pumps, is of course allowable when the condensate is not to be saved for study.

The interior heating element is a simple flat helix of tubing, ¼ inch inside diameter, having preferably a moderately thick wall, say 1/32 inch. The flat coil is so placed as to be just above the bottom of the pan inside, and it is held in place by the vertical inlet and outlet tubes extending through the cover. It would be of course be possible to pass these through some type of stuffing box, but it is the writer's experience that it is well to have this heating element not too firmly held in place, and the rubber stopper arrangement has given satisfaction. Of course, also, the steam coil may be omitted, and the pan heated by an external steam, hot water or oil bath; but this method is less efficient, although desirable if the substance is to be evaporated to dryness. When using the internal steam coil it has been the writer's practice to deliver the exhaust steam and condensed water into a loose jacket surrounding the bottom of the pan, and provided with an overflow, thus reducing loss of heat from the exterior of the pan.

To operate the pan it is set up and connected to the vacuum pump, with or without the condenser, as preferred for the work at hand, and tested empty to ascertain how high a vacuum it will maintain with the pump running. Some small leakage always occurs, but unless this is very bad it will influence the working vacuum but little when a pump of sufficient power is used. Much depends upon the evenness of the surfaces of the body flange and the cover, and the nature of the gasket or washer used. For the latter a good quality of red rubber packing ⅛ inch thick has been found best. When the operation is satisfactory from this standpoint, the liquid to be evaporated is admitted through the separatory funnel, preferably not more than a quart being admitted at first, and further additions made at the rate of a pint at a time as the collection of the condensate indicates. As much as two quarts may be used initially in the 13-inch deep pan, but if the liquid foams severely this amount will usually cause foaming over into the condenser. Various forms of foam traps have been devised, but ordinarily none are quite as satisfactory as not starting with too much liquid.

When the desired amount of evaporation has taken place the apparatus is disconnected from the vacuum, being careful to open the vacuum break first, especially if a water-jet pump is used, when there is no stop-cock between the pump and the pan. The cover, which has been held on by means of small clamps, when the vacuum was being established, is removed, and as much of the liquid as possible allowed to drain from the steam coil. The whole pan is then inverted, and the contents allowed to drain into a receiving vessel.

PROPOSED 220,000-VOLT TRANSMISSION SYSTEM.

THE proposed "California Transmission Bus" is an overhead line to connect the power systems of Pitt River, Feather River, Big Creek River and Colorado River. The line will have a total length of 1,100 miles and will handle 1,500,000 kw. at a working pressure of 220,000 volts.

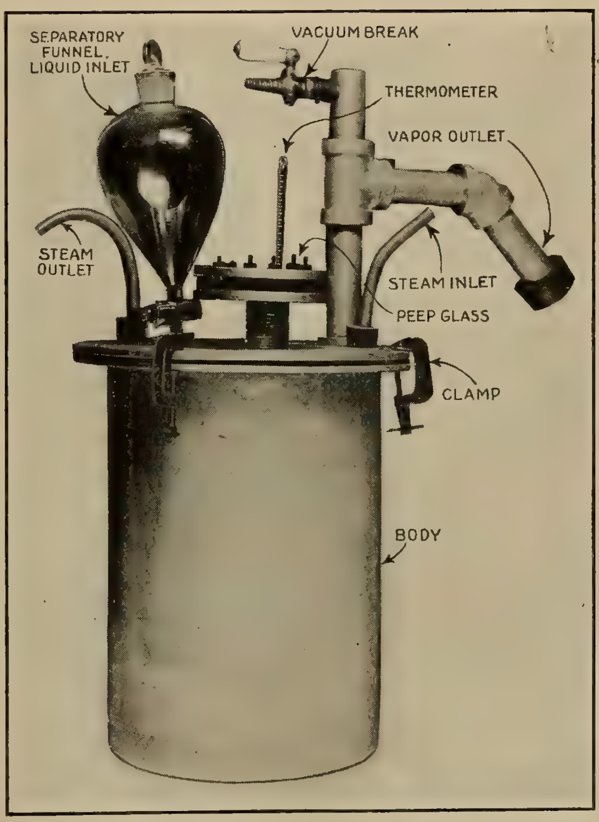


FIG. 4. THE FINISHED VACUUM PAN READY FOR USE

Danger of Automobile Exhaust Gas

Need of Investigating Conditions in Vehicular Tunnels

By Van. H. Manning, Director, U. S. Bureau of Mines

THE rapidly increasing use of motor vehicles and trucks in the United States is creating an entirely new problem in the proper ventilation of tunnels, subways and other confined places where such machines must pass through. The traffic congestion in our larger cities, due to motor trucks and automobiles, is becoming so great that subways or double-decked streets will soon be required to relieve the situation; indeed, Chicago is now double-decking Michigan Boulevard along the lake front in the downtown district. The upper street level is to be used by passenger cars and the lower level by heavy trucks. The danger of poisoning from the automobile exhaust gases in the confined lower level is serious, probably more so than generally realized.

However, a much more dangerous condition may arise in long street and vehicular tunnels which must depend entirely on artificial ventilation for the removal of deleterious gases. Tunnels of this character are now under consideration in a number of different places in the United States, and the Bureau of Mines has received several requests for information on the physiological effect of automobile exhaust gases and on the amount of deleterious gases that are emitted from automobiles and trucks under various conditions of use. Such information is required by engineers who are charged with designing the ventilating equipment for tunnels. Engineers are agreed that present information is inadequate and unless reliable data is provided by further investigations the public will suffer either acute physical discomfort and illness from breathing polluted atmospheres due to insufficient ventilation. or the public purse will have to bear the fixed charges of excessive overventilation.

NATIONAL ASPECT OF PROBLEM.

It is just and proper that the Federal Government should investigate this problem rather than local communities or states. Tunnels are being considered in many parts of the United States. The largest one for which immediate information is wanted is the proposed vehicular tunnel between New York and New Jersey under the Hudson River. This tunnel will be 9,000 feet long and will have an estimated maximum number of 2,000 automobiles and trucks per hour passing through it during rush periods. The amount of poisonous gas given off by this long line of machines is almost beyond conception, certainly it cannot be guessed at. That this fact is fully appreciated by the New York State Bridge and Tunnel Commission and the New Jersey Interstate Bridge and Tunnel Commission is shown in a letter from the chairman of the two commissions to the Secretary of the Interior asking the Bureau of Mines to conduct investigations on automobile exhaust gases with respect to tunnel ventilation.

The South Hills Tunnel at Pittsburgh, Pa., now being designed, will be a little over a mile in length and will be used by a great many passenger autos and trucks. Mr. Neeld, Chief Engineer, has consulted the bureau's experts on ventilation and has based his design largely on the fragmentary data provided in the Bureau of Mines investigations of "Gasoline Mine Locomotives in Relation to Health and Safety" (Bulletin 74). Vehicular tunnels are also being considered in Louisiana, California, under the Delaware River at Philadelphia, under the East River at New York and in Boston, Mass.

POISONOUS CHARACTER OF AUTOMOBILE EXHAUST GASES.

That the general public is beginning to appreciate, in a measure, the poisonous character of automobile exhaust is shown by the following clipping from the *Pittsburgh Sun* of November 30, 1919, under the caption of "Chemistry in Every Day Life," by "Crucible."

"Poisoning from Automobile Exhaust."—It is not uncommon to read about finding a man dead in his garage. When this happens the account goes on to state that the engine was running, and that the doors and windows were closed. The natural conclusion is that there must be a poisonous product generated by the engine, and that this product accumulated in the closed garage in sufficient quantities to cause death.

The experts of the Bureau of Mines[1] as well as various automobile engineers have investigated this problem and the cause of the poisoning and the conditions that produce the poison are pretty well understood.

The poison is a gas, carbon monoxide by name. It is the same thing that miners find after mine fires or explosions, and they call it "black damp." People who use coal gas have to watch out for leaks because of the presence of carbon monoxide in the gas.

Carbon monoxide has no color, taste, or smell. It has nothing to do with the cloud of smoke that pours out of the exhaust pipe of a car once in a while. There may be, and probably is, carbon monoxide in the smoke, but it isn't monoxide that you see.

Practically speaking it is impossible to run an automobile engine without producing carbon monoxide. In the course of this investigation tests were made where none was produced, but it was done by using a mixture so "lean" that the average engine will not start on it if cold, and very few carburetors are adjusted to use such a mixture at all. Furthermore, the difference between the production of a large amount of carbon monoxide and none at all is so slight that a carburetor if adjusted would not continue to deliver the mixture more than a few moments. An example will show this. A mixture containing 4.1 parts of gasoline vapor in 100 parts of mixture gave an exhaust on a 30 horse-power engine that contained 14 per cent of carbon monoxide, while with a mixture of 2.5 parts gasoline vapor in 100 no carbon monoxide was produced.

Further experiments along this line carried out on 13 different automobile engines with good mixtures and very rich mixtures showed in the first case amounts of carbon monoxide varying from 10 to 36 cubic feet of carbon monoxide produced each minute, while the results with rich mixtures gave from 135 to over 600 feet a minute.

Carbon monoxide is very poisonous. The presence of one part of the gas in 500 parts of air will cause a person to collapse within an hour, while larger amounts will shorten this time.

In order to see how soon the air in a garage might be affected by the running of an engine, samples of the air were collected while a 30-horse-power engine was operating. It was found that in less than 15 minutes a dangerous amount of gas had accumulated around the car.

It follows that an engine should never be run in a closed garage. Dangerous amounts of poisonous gas will be present in the air before there is time to do much repair work.

It is not much pleasure to work over a car on a cold winter day with the garage doors wide open, for no matter how much of a heating system there may be the building will soon get pretty chilly. It is possible to fix up a simple arrangement that will get around the discomfort of working practically out of doors, and at the same time be perfectly safe. A short length of hose one end of which is slipped over the exhaust pipe while the other end reaches out doors will do the trick

[1]Technical Paper 216, "Vitiation of Garage Air by Automobile Exhaust Gases," by G. A. Burrell and A. W. Gauger.

provided it is not necessary to open the cut out while the engine is running.

If you feel a dull, depressing sort of a headache with a faint spell or two after working over a car you have probably got too much carbon monoxide. Not enough to be really dangerous but a warning. If you feel very faint a doctor should be called in at once as after one has actually collapsed recovery is difficult.

EXHAUST GASES FROM GASOLINE ENGINES IN TUNNELS.

Although data which directly show the conditions which are to be encountered in long street tunnels are not available, some investigations on the composition of automobile and other gasoline engine exhausts have been made. Some of these deal with mines. This data may be used for showinng the possible conditions in the tunnel until experiments are made which exactly apply to the problem.

Chase[2] made experiments with twelve passenger cars and three trucks, all representing different types which were run over city streets under various conditions. Samples of the exhaust gases were secured and analyzed usually on nine different runs for each car.

A general summarizing of the results shows a maximum production of 6.8 per cent of carbon monoxide in the exhaust gases, an average of 2.1 per cent and minimum of zero per cent. While these figures are of some value, it is believed that more carbon monoxide is produced in the average car of today.

The cars tested were comparatively few in number, the carburetors were purposely put in good adjustment, and the grade of gasoline has changed since 1914, so it is doubtful if they represent the average for street traffic today. The low percentage of carbon monoxide found from the three trucks certainly does not show the range of carbon monoxide from trucks in general.

The Bureau of Mines has made experiments with mine locomotives run by gasoline engines with a view to safety from poisonous constituents in their exhaust gases in mines. The following extract from Bulletin 74[3] is of general interest in this connection:

"The process of combustion in the cylinder is affected by several variables: some are under the control of the motorman whereas others are not. Owing to the variety of variable factors it is difficult to duplicate conditions exactly, either in practice or in the laboratory, in order to study the effect of a single variable. The operator of a gasoline locomotive can readily observe only two variables—namely, the speed of the engine and the ability of the locomotive to pull its full load. From these he infers the existence of any wrong condition and then makes various adjustments to right it. These adjustments may result in producing exhaust gases of widely varying character and still enable the engine to pull the load. If the adjustments are not skilfully made the engine may lack both speed and power and the exhaust gases again be changed in character. Some combination of speed, power, and poor adjustment will produce the maximum quantity of noxious gases. This combination exists when the engine is using the maximum quantity of gasoline on which it can pull the full load at the full speed. Greater percentages of noxious gas can be made when throttling the mixture to suit conditions of half speed and half load, but the total quantity of noxious gases produced is less because of the reduced speed. The most dangerous condition of a locomotive as a producer of noxious gases, therefore, is when the engine is working at full speed and with full load and is using the most instead of the least gasoline that it can use to maitain the speed.

"The exhaust gases consist of the products of both perfect and imperfect combustion of the fuel. Analysis shows them to be a mixture of carbon dioxide, carbon monoxide, oxygen, nitrogen, hydrogen, and water vapor, and also, it is believed, small but negligible quantities of gasoline vapors."

The paper also gives a table which presents probably the best data now available for use in safeguarding persons in street tunnels.

The amount of carbon monoxide produced by the smaller mine locomotives may be comparable to that produced by trucks, but not necessarily so.

In other experiments the Bureau[4] studied the vitiation of garage atmosphere by automobile exhausts. A 30-horse-power, four-cylinder engine of an automobile truck was allowed to run in a closed garage of about 5,000 cubic feet capacity. Samples of air from different parts of the garage were secured at different times and analyzed. In the comments on the results this statement is made:

"It is interesting to note that at the back of the automobile, at B, there was a slightly higher percentage of carbon monoxide in the sample taken near the floor than in the sample taken six feet from the floor. This is not surprising in view of the fact that the exhaust gases are expelled about a foot above the floor. Dangerous amounts of carbon monoxide were present in the farthermost parts of the garage after the engine had run 20 to 30 minutes, whereas near the machine the air was extremely unsafe when the engine had run about 15 minutes."

The fragmentary information cited above will enable engineers to draw enough approximation of the ventilation needs of city street tunnels but it is still quite insufficient for the needs of the case. If one considers that the well-being of thousands of people daily is to be carefully safeguarded, many of whom are constitutionally able to withstand only minute quantities of the gases which pollute tunnel air, the need of precise information is apparent.

INJURIOUS CASES OTHER THAN CARBON MONOXIDE.

In the foregoing matter carbon monoxide has been assumed to be the only harmful constituent of tunnel air. That other gases or vapors may be present is well shown in the extract below from a letter dated November 10, 1919, received by the Bureau from E. W. Roberts, Editor of *The Gas Engine*, published at Cincinnati, Ohio. The letter is also typical of other requests for information on the subject:

"It is not generally known exactly what the physiological properties of gasoline vapors are. From experiments that the writer has made, he has found that petroleum vapor has anaesthetic properties. Reference is made to this subject on page 647 of Brants 'Petroleum and Its Products.' As the bulk of gasoline vapor at ordinary temperatures consists of pentane, we believe that the properties of this material are those to be considered.

"Experiments have been made on animals, the results of which are confirmed by a number of experiences of persons who have worked in an atmosphere of gasoline vapor and show that pentane vapor when mixed with oxygen produces a stupor. An odd phase of this subject is that persons have worked in an atmosphere heavy with gasoline vapor and experienced no ill effect until after they have passed to an atmosphere entirely free from the vapor.

"In order to explain this matter more definitely, I will cite two instances:

"The owner of a small private mine near New Philadelphia, Ohio, some years ago was working with a plumber in a room off the main air way repairing a pump driven by a gasoline engine. The carburetor of the engine was flooding and they had difficulty in starting it. It was asserted afterward that they were working in this atmosphere heavy with-gasoline, for approximately one hour. On leaving the room

[2]Chase, H., Exhaust gas analysis for economy: *The Automobile,* Vol. 30, 1914, pp. 395-9, 422-6, 469.

[3]Hood, O. P., Kudlich, R. H., Gasoline mine locomotives in relation to safety and health, with a chapter on methods of analyzing exhaust gases: *Bureau of Mines,* Bulletin 74, 1915, p. 83.

[4]Burrell, G. A., and Gauger, A. W., Vitiation of garage air by automobile exhaust gases: *Bureau of Mines,* Technical Paper, 216, 1919, p. 12.

and going to the main air way both the plumber and the mine owner collapsed a short distance from the opening into the room. The plumber fell with his face in a pool of water and drowned. The mine owner was later discovered by a rescue party and revived.

"A similar case is one which occurred at Chicago some years ago. A man was working in his garage, with closed doors, adjusting a carburetor which was flooding. He was called to the telephone and collapsed a short distance from the garage after getting out in the open air.

"Our reason for calling your attention to the peculiarity of gasoline vapors, is that we believe that it might be worth while investigating, particularly as these effects are almost invariably attributed to carbon monoxide poisoning.

"Should you find this matter to be of sufficient interest to follow up in the experimental way, the writer will be very glad to learn the results of your tests."

WHAT SHALL BE THE MAXIMUM ALLOWABLE PERCENTAGE OF CARBON MONOXIDE IN TUNNELS?

In order to render tunnels safe for those using them sufficient air must be introduced into the tunnel to so dilute the exhaust gases that the percentage of carbon monoxide is reduced to a point where it becomes harmless. After sufficient experiments have been made to determine how much carbon monoxide is given off by various automobiles and trucks, the next question that arises is the maximum allowable per cent of carbon monoxide that will do no harm. Is it 0.1 per cent or 0.01 per cent or somewhere between these limits? Physiological authorities differ in their opinion over this range. This divergence appears to be due to a lack of sufficient experiments. Dr. Haldane, the noted English authority, recommended 0.01 per cent carbon monoxide as the safe limit for the atmosphere in the Metropolitan Tunnel in England. Other authorities think that the concentration may be increased to nearly 0.1 per cent for short periods of time.

Another very important phase of this problem is the effect of carbon monoxide and exhaust gases on women, children and persons in delicate health. Individuals that are anemic or affected with heart disease are undoubtedly affected by smaller percentages of deleterious gases than normal individuals. Most of the work heretofore done on carbon monoxide poisoning has been with reference to workmen in mines and in the industries. The data thus obtained is not directly applicable to tunnel conditions, where all sorts of individuals, and a less robust average must be considered.

Large Electric Steel Smelting Furnaces*

Some Interesting Phenomena

By Victor Stobie

Large electric arc steel-melting furnaces are preferable for ingot making, but smaller furnaces have a very large field in foundry work. Observations will be confined mainly to large plant and to some interesting phenomena on all furnaces.

WIRING DIAGRAMS AND SHAPES OF FURNACES.

The wriing diagrams (Figs. 1, 2 and 3) give the best connections for three sizes of furnaces. Fig. 1 is for furnaces up to 6 tons' capacity, two-phase current, each phase maintained entirely separate from the other, with one end of each phase connected to separate electrodes above the bath, and the other end of each phase connected to separate electrodes embedded in the hearth of the furnace at opposite ends of the furnace to their relative top electrodes. This arrangement gives the requisite bottom heating for small furnaces and leads to crossing of the currents in the direction of flow through the bath. Fig. 2 is for furnaces from 6 tons up to 24 tons' capacity, two-phase current, each phase maintained entirely separate from the other, with each end of each phase terminating in an electrode above the bath. Bottom electrodes, while essential in small furnaces, are undesirable in large furnaces. Fig. 3 is for furnaces above 24 tons' capacity, three-phase current, each phase maintained entirely separate from the others, with each end of each phase terminating in an electrode above the bath.

The most favorable shapes for tilting electric furnaces would appear to be:

Up to 6 tons: Rectangular in plan and in elevation with a curved bottom.

From 7 to 24 tons: Octagonal in plan.

Above 24 tons: Octagonal with lengthened back and front walls.

Stationary furnaces should always be rectangular.

The above shapes ensure the most convenient position for the electrodes in the furnace and help to keep the furnace walls at the average greatest distance from the electrodes, which should not be opposite to doors, in order to avoid the breaking of electrodes when material is thrown into the furnaces.

*Abstract by the *Electrician* (London) of a paper read before the Institution of Electrical Engineers.

ARC PHENOMENA.

The arc phenomena in a steel-melting electric furnace are important and interesting. The arc proper jumps between the bath and whichever portion of the electrode is nearest. As this point is always changing, the arc travels irregularly round and under the lower extremity of the electrode. A flame of carbonaceous gas, in large furnaces as much as 2 feet long, travels over the bath from each electrode. This is quite the hottest flame in commercial use and in some designs of furnaces, causes excessively quick burning away of the roof and door arches. It will rapidly flux the banks of the furnace if allowed to impinge thereon. Some control can be obtained over the direction of the flame by alterations in the direction of rotation of the magnetic field of the supply currents. Experiments on the blowing of the arc flames in furnaces by strong external continuous magnetic fields were also made.

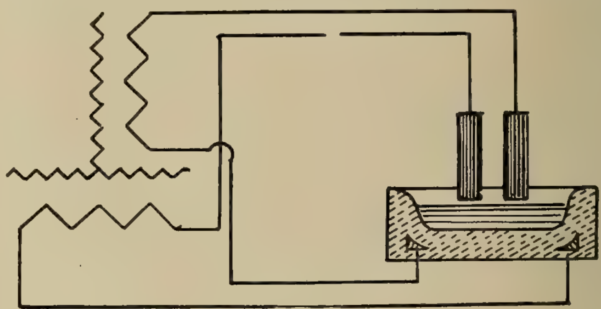


FIG. 1

In some types of electric furnaces arcs are maintained between adjacent electrodes and not between electrodes and bath. The property of inter-repulsion of arc flames is utilized to fan the flames over the material to be melted, while much of the heat energy in the circuit, viz., that in the arcs proper,

travels only between the electrodes. This leads to a high current consumption per ton of steel in such furnaces. It was once believed that the great heat (*circum.* 3,600° C.) of the arcs in an electric furnace would have a detrimental effect on the steel. More recent experience teaches us that, so long as a steel is thoroughly deoxidized before casting, only the temperature of casting is of moment.

TRANSFORMERS.

One might, with reason, say that the heart of the electrical equipment of an electric furnace installation is the transforming apparatus. The stresses which the transformers have to resist are exceedingly heavy. The plant has to withstand occasional short-circuiting through the furnace and even the equivalent of almost a dead short-circuit. It has to allow frequent breaking of the circuits under heavy overload and, possibly, of occasional switching direct on to overload.

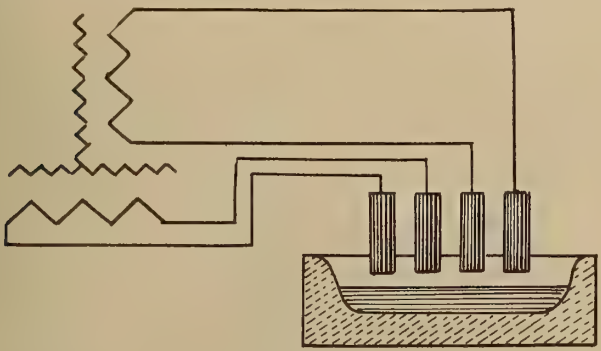


FIG. 2

The requirements in the design of the transformers are:

1. That the current density of both the low-tension and extra-high-tension windings shall be low enough to prevent the inevitable overloads from unduly heating up and deteriorating the insulation.

2. The ventilating channels in the windings must be specially well considered so as to provide low resistance paths for the cooling oil without excessive magnetic leakage.

3. That windings shall be braced on all sides.

4. The low-tension windings shall be taped with such material as empire tape, in addition to press-spahn or similar stiff insulation.

5. All clamps, no matter how small they may be, should be anchored to the transformer frame work.

6. The whole of the apparatus must be as unyielding to magnetic stresses as mechanical skill can make it.

7. As much as possible of the total reactance required in the whole of the furnace installation should be incorporated in the transformers.

As a result of observations of the breakdown of some furnace transformers, the bracing of all sides of the windings of transformers was specified by the author in 1917. The design has now been standardized also for large power transformers.

It is usual to have several tappings brought out from the high-tension windings of furnace transformers, as the voltage required on a furnace during melting is higher than when finishing a heat. Such tappings should be brought away from the central portions of the winding, the complete high-tension winding being divided into two at the mid-point and the tappings bridged across the mid-point to cut out equal portions of each half of the windings when required. The insulation of the end turns of the high-tension windings can then be suitably reinforced to withstand any abnormal voltage stress on switching in the transformers. Useful results have been obtained by limiting the current density in transformer windings to 1,250 ampere per square inch, the induction in the iron to about 12,000 C.G.S. lines, and the temperature rise on continuous full load to 45° C., measured by the increase in resistance. An over-potential test at this double voltage is made on the high-tension side. Low-tension windings of large furnace transformers should be tested at a potential several times greater than normal.

AUTOMATIC ELECTRODE REGULATORS.

The desiderata in automatic regulation mechanism include sensitiveness without fragility, and simple setting to limits. If the furnace circuits contain two arcs in series, the energy in each such two arcs should be balanced, whatever current is flowing. This is accomplished in Stobie electric furnaces by operating one electrode motor by an automatic current controller and the other by an automatic potential controller. The current controller is adjusted to give the limits of current required and will keep its electrode at any position at which such desired current will flow. The potential controller is adjusted so that half the phase voltage, *i. e.*, the normal voltage between one electrode and the furnace charge, is maintained on the electrode it controls. The result is that the potential-regulating motor will keep its electrode at the same distance from the molten steel as the current-regulating motor keeps the other electrode, as at that distance the current will be normal and the voltage balanced. On some electric furnaces balancing of two arcs in series is automatically controlled in a different manner.

POWER FACTOR.

The power factor of alternating arcs varies from almost unity to lower than 0.7 in the case of arcs between cold hard metals. As is known, the apparent resistance of an arc varies with the current passing through it, being high for a low current. The voltage wave consequently is distorted and forms a sharp peak at the commencement and end of each half cycle, with a strongly marked depression between. The current wave approximately retains its sine shape, and a lagging power factor results without any phase displacement.

The circuit reactances are divided between the transformers and the leads. Due to the large sizes of conductors used, and to the large area enclosed by the circuits, reactance in furnace work has a tendency to be high. At the same time, very low reactance would be undesirable on large power systems in view of the frequent short-circuits through the furnace. The total impedance on short-circuiting through a cold charge will usually be high enough to reduce all shocks to reasonable limits. If, however, a short-circuit takes place through a molten steel bath, the impedance will be relatively low on account of the good conductivity of the bath, unless a reasonable amount of reactance is incorporated in the circuits. Such short-circuits are, fortunately, very rare in well-designed furnaces. The total impedance at the moment of starting a large furnace with poor scrap sometimes reaches over 90 per cent. With average scrap it ranges between 40 and 60 per cent. When melting armor scrap or other clean heavy material it little exceeds the reactance.

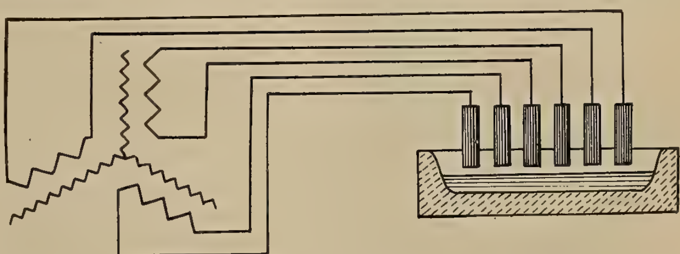


FIG. 3

A 15-ton Stobie furnance gives the following power factors:

On melting	0.84
When charge is half melted	0.85
When charge is almost melted	0.87
When charge is melted	0.93

It can be safely stated that large furnaces such as the 10-ton, 15-ton, and 20-ton Stobie furnaces give an average power factor of fully 0.88 over all units consumed.

The author has heard it stated at various times that one or other particular design of furnace can be worked safely at

almost unity power factor. The author aims at installing plant in such a manner that on dead short-circuit the power factor is momentarily reduced to 0.4 or even 0.3.

ELECTRODE CONSIDERATIONS.

The presence of electrodes in electric arc furnaces is, for the user and designer, an unfortunate necessity. The desirable characteristics of an electrode are: low resistivity, relative incombustibility and cheapness. No material combines these qualities. The nearest approach is found in carbon, and one has the choice between amorphous and graphitic carbon, electrodes. The following table gives the comparative data of both types of electrodes:

	Specific resistance per cm. cube.	Lowest temperature of combustion.	Diameter to carry 10,000 amps.
Amorphous electrode....	0.00332 ohm.	513°C.	12 in.
Graphite electrode......	0.00114 ohm.	624°C.	20 in.

A very important point, almost invariably overlooked by designers and users of electric furnaces, is "skin effect." The average current density in the main current-carrying area of an electrode being roughly twice the average current density of the whole area, due to skin effect.

The main consumption of the electrodes in ordinary electric steel furnaces does not take place at the arcing end of the electrodes, but results from the surface burning of the carbon all over those parts of the electrodes which are inside the melting chamber and up to a point about 15 inches above the roof. Fully 75 per cent of the heavy expenditure on electrodes is wasted through this defect. Various attempts to prevent this costly waste of electrodes have been previously made, such as (1) enveloping the carbons with asbestos paste held in position by wire netting; (2) coating the electrodes with non-burning paints; (3) encircling the electrodes with steel collars held together by hinges or springs; (4) surrounding the electrodes with water-cooled cyliders extending well inside the furnace. All such methods have met with failure.

It is thought by some people that there is always a reducing atmosphere inside electric furnaces. This is an utterly mistaken notion. The cause of the oxidizing atmosphere inside the older electric furnaces is the crude method of feeding the electrodes into the melting chamber, *i. e.*, by leaving in the roof a number of plain holes equal to the number of electrodes which have to be continuously fed into the furnace; the bricks forming such holes support annular water-jackets which fit, with a small clearance, new electrodes. The heated gases inside the furnace continuously pass up those clearances between the roof and the electrodes. As a result the clearance being increased by the flames burning away the electrodes to a tapered point, the heat value of the gases and flames which are constantly pouring out of the furnace through the electrode holes is wasted.

The clearance may be closed in this way: At about 2 feet above the roof in most furnaces the electrodes, even when raised for charging, are seldom at a temperature at which they can burn, therefore, that is the only point at which a permanently good seal can be made round the electrodes.

In practice, a light metal cylinder a few inches larger in diameter than the electrode and about 2 feet in length is fixed on the roof round each electrode. The top end of the jacket is covered with a sealing plate, the electrodes passing through a neatly fitting hole in the center of such cover.

Fig. 4 shows the present-day economizer, which can be applied in telescopic form suitable for furnaces having only a short electrode travel. Other advantages of this simple device are as follows:

1. No cold air is drawn into the furnace.
2. No flames burn away the electrodes above the roof.
3. A really reducing carbon-depositing (when desired) atmosphere is maintained within the melting chamber.
4. The oxygen-free atmosphere of the furnace prevents the burning of the electrodes inside the furnace except at the arcing ends, and, therefore, electrodes do not taper.
5. The electrodes can be of smaller diameter for a given current supply, thus diminishing electrode costs and permiting a reduction in the size of the electrode holes in the roof.
6. The life of the roof is increased because the thick carbonaceous atmosphere inside the furnace acts as an opaque curtain through which the intense heat of the arcs cannot be radiated upwards.
7. The flames inside the furnace, not being able to pass out at the electrode holes, travel all over and among the charge and heat this up readily and very economically.
8. The electrode gear over the furnace does not become intensely hot as in older furnaces. Any adjustments can, therefore, be made in comfort.
9. In consequence of the exclusion of free air from the furnace, and the absolute control which this permits over oxidation, scrap steels containing oxidizable elements, can be easily melted without losing the special elements from the bath.

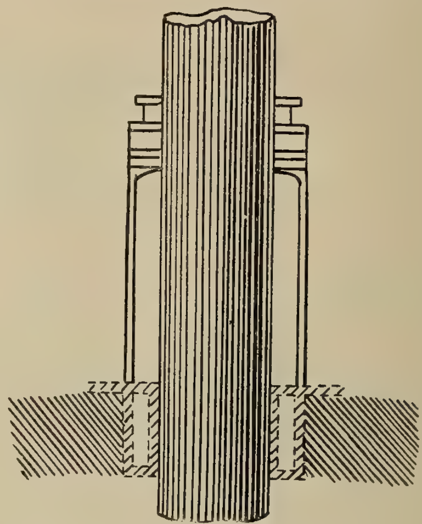


FIG. 4. ELECTRODE ECONOMIZER

10. The absence of heat from the electrode gear enables the current terminals of the electrode to be made of light copper contacts built up of standard copper bars, instead of intricate, heavy, water-cooled bronze castings.
11. By preventing the heavy heat losses which formerly took place, the cost of manufacturing electric steel has been reduced and the time required per heat diminished.
12. The sealing of the roof of furnaces results in the furnace being much cooler for the furnace men to operate.

CIRCULATION OF BATH.

It was decided to devise means whereby closer observation of the effects of electric circuits through molten metal could be made than was possible in a steel furnace working at temperatures up to 1,800° C. Mercury presented itself as a suitable substitute for a hot steel bath, being magnetically inert. Its resistivity at atmospheric temperature is approximately two-thirds and its specific gravity twice that of molten steel.

Separate experiments with single, two-phase and three-phase currents, and representing every known type of furnace with arcs playing on the bath, were made.

Two voltages were separately used for each system of connections; one low enough to enable the full current to be passed through the bath without arcs, and a higher one to pass the current through arcs above the bath as in normal steel melting.

The research conclusively proved that no circulatory or other stirring movement of the bath results from the electrode circuits in an electric arc furnace. The more or less complete diffusion of added elements which takes place in a bath of molten steel is a metallurgical phenomenon, and does not depend upon magnetic or convection currents.

The Hvid Engine*

Its Relation to the Fuel Problem

By E. B. Blakely

IT has been estimated that internal-combustion engines now furnish approximately two-thirds of all the prime motive power generated in the world. These internal-combustion engines may be roughly divided into three classes:

a Those burning gasoline

b Those burning kerosene, tops and other light distillates, after being started and warmed up on gasoline

c Oil engines of the Diesel, semi-Diesel, hot-bulb and surface-ignition types, which use for fuel crude oils, fuel oils and cheap grades of kerosene.

Of these three classes the first furnishes about 95 per cent of all prime motive power, and it has been estimated that there are in use now in this country, burning gasoline, nearly 4,000,000 automobiles, 250,000 trucks, 500,000 motor boats, 75,000 tractors and 750,000 farm engines. Is it any wonder, therefore, that the demand for gasoline has increased?

By ordinary distillation methods, Eastern crude oils yield from 20 to 30 per cent of gasoline, Mid-Continental crudes from 16 to 20 per cent, and Gulf, California and Mexican oils from 2 to 3 per cent. The rough average of these is 15 per cent. The visible supply of crude oil is naturally diminishing, and since the oil is becoming heavier all the time the percentage of gasoline yield is lessening.

The supply of gasoline may be increased slightly by making use of the cracking processes, which would necessitate an increased cost of production, and also by blending high-test casing-head gasoline with kerosene, a process bound to be short-lived because our gas wells are rapidly giving out. The supply of gasoline may also be conserved by increasing the thermal efficiency of the engines and by adapting them to burn kerosene and mixtures of gasoline and kerosene. The relief gained, however, would be but temporary at best. We are having trouble enough now in burning properly the present-day gasoline without trying to burn all sorts of mixtures which at the least would necessitate constant changing of carbureting adjustments and methods.

Much has been written and said during the past two or three years on the subject of using kerosene as fuel in conventional gasoline engines of both the slow-and high-speed types, and while undoubtedly much has been learned concerning the characteristics of kerosene under certain conditions, the burning of kerosene in gasoline engines, so far as the writer knows, has not been accomplished with complete success up to the present time. By complete success he means starting the engine on kerosene in atmospheric temperatures approximating 0 deg. fahr. and below (for these must be reckoned with) without preliminary heating of any sort and burning the kerosene so as to eliminate troublesome carbonization and complicated and unsightly accessory apparatus, and obtain high economy.

In attempting to burn kerosene in modified gasoline engines we are confronted by the following basic difficulties: Kerosene and gasoline are chemically widely different substances, having nothing in common but the base from which they are derived. Their initial boiling points are wide apart, that of commercial gasoline being about 100 deg. fahr., while that of kerosene is about 330 deg. fahr. Their boiling ranges are also totally different, that of gasoline being 240 deg. fahr., while that of kerosene is about 200 deg. fahr. Gasoline-air mixtures will ignite spontaneously at approximately 680 deg. fahr., while similar mixtures of kerosene and air self-ignite at approximately 575 deg. fahr. Mixtures of gasoline and air form a permanent fixed gas, but mixtures of kerosene and air do not, Under these conditions a jet carburetor designed for vaporizing gasoline cannot be expected to vaporize kerosene. The best it can do is to atomize it.

In order to vaporize, as well as to prevent precipitation or condensation of the atomized kerosene in the combustion chamber, it is necessary to heat the charge, and since the power output of the engine depends upon the amount of oxygen taken in and burned during each cycle, it is clear that the more the charge is heated the less oxygen we can get into the cylinder and the less power we can obtain. This forces us to a compromise between two conflicting conditions: the maintenance of the incoming charge at the lowest possible temperature which will vaporize the kerosene, and the prevention of precipitation in the combustion chamber. This compromise might be satisfactorily effected in the case of an engine running at a constant speed and load, but in the case of an engine running at varying speeds and loads it is a very different compromise to make, because as the power demands on the engine vary, so must the total amount of heat added to the charge vary.

In order to obtain maximum power from any internal-combustion engine, regardless of the kind of fuel used, we must have maximum mean effective pressure, and since mean effective pressure depends largely upon compression pressure, we must use the highest compression pressure possible. This brings us again to a conflicting pair of conditions, because in order to prevent so-called preignition with its attendant disagreeable and harmful pounding, when burning kerosene we are forced to use a relatively low compression pressure, which lowers the mean effective pressure and also the power output.

In this connection may also be mentioned the so-called preignition knock which occurs when using too high a compression pressure with kerosene. This knock is not caused by

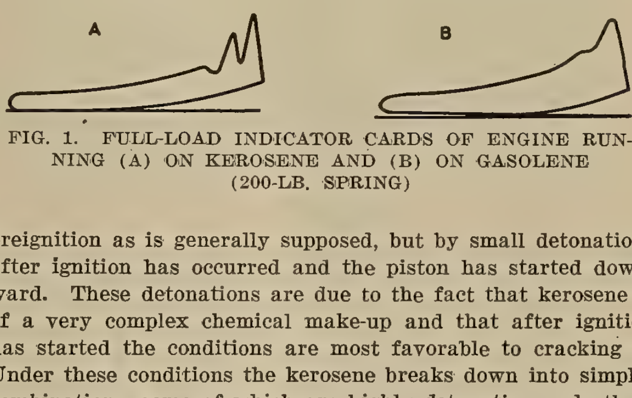


FIG. 1. FULL-LOAD INDICATOR CARDS OF ENGINE RUNNING (A) ON KEROSENE AND (B) ON GASOLENE (200-LB. SPRING)

preignition as is generally supposed, but by small detonations after ignition has occurred and the piston has started downward. These detonations are due to the fact that kerosene is of a very complex chemical make-up and that after ignition has started the conditions are most favorable to cracking it. Under these conditions the kerosene breaks down into simpler combinations, some of which are highly detonating and others less so, and these compounds set one another off successively, according to their stability, but so rapidly as to produce a single knock.

That this is so, is clearly shown by comparing the two full-load indicator cards shown in Fig. 1. They were both taken from the same engine but with different cylinder heads and operating with different governors. When *A* was taken the engine was running on kerosene (43 deg. B.) with no water injection, after having been warmed up on gasoline. A throttling governor was used. When *B* was taken the engine was operating on gasoline (62 deg. B.) and with a "hit-and-miss" governor. The compression ratio was 5 to 1.

Many engineers believe that if the problem of utilizing kerosene for fuel in these engines now burning gasoline could be solved, the whole fuel problem would be solved. It undoubtedly would help the situation immeasurably, but who can

*Paper presented at the Annual Meeting, December 1919, of *The American Society of Mechanical Engineers.*

doubt for a moment that the price of kerosene would not soar, once the demand for it began to grow, until finally there would be but little difference between the prices of gasoline and kerosene. The true economic solution of the fuel problem lies not in trying to adapt some particular fraction of the distillation of crude oil to the engine, but in adapting the engine to the available fuel, whether it be crude oil just as it comes out of the ground, or some by-product of its distillation.

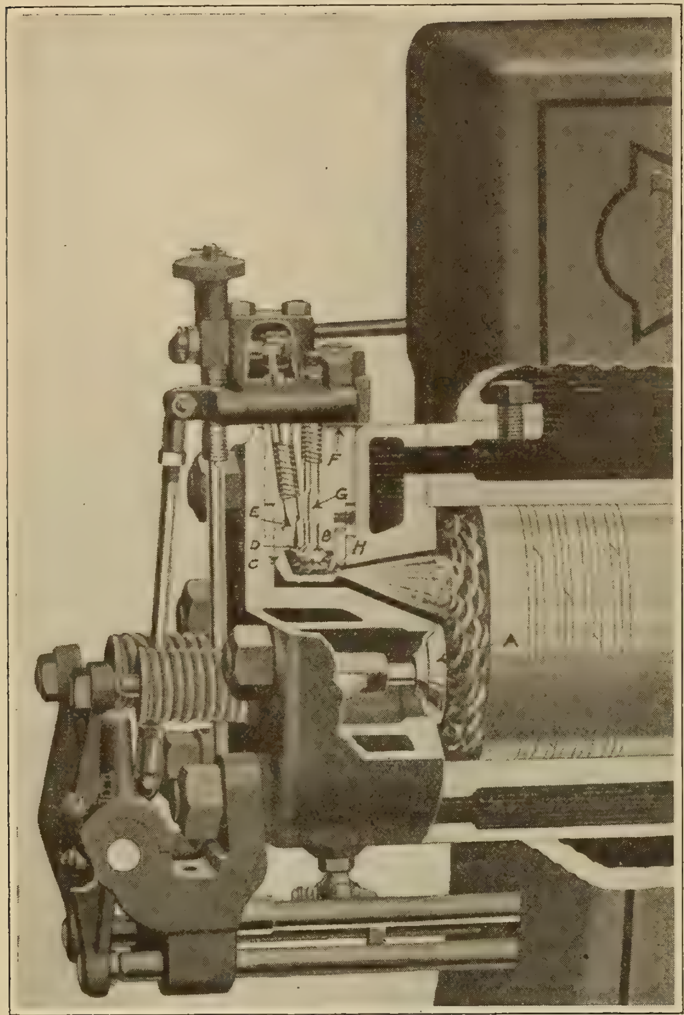


FIG. 2. CUTAWAY SECTION OF 8 H-P. HVID-TYPE FARM ENGINE

There have been numerous engines built in the last ten years capable of running consistently on the various crude and fuel oils, as for instance the Diesel and so-called semi-Diesel engines, hot-bulb and surface-ignition engines. These, however, have been used mainly in marine work and in relatively large units. It is out of the question to consider making Diesel engines of much less than 100 hp. per cylinder, because of the complicated fuel-injecting mechanism and the high cost of production. The other types have the disadvantage of requiring external preheating before they can be started, and the torches used for this purpose are a source of constant danger. Electric preheating has been tried, but with little success.

There is an engine, however, which has all the advantages of the above mentioned types and none of the disadvantages. This is the Hvid engine. It can be started cold on any liquid fuel which will flow through a pipe. It has no complicated air-compressor system for injecting the fuel, no hot bulbs or torches, and runs with a fuel economy on a par with the Diesel engine. The Hvid engine can be and is being produced in units as small as 1½ hp., and so economically as to be able to compete with gasoline engines of the same size.

ADVANTAGES OF THE HVID ENGINE

A comparison of the Hvid engine of the farm type with a conventional gasoline engine of the same type discloses many factors which show the superiority of the former for this class of work. The Hvid engine has neither electrical devices nor carburetor or mixer. It starts readily on any liquid fuel, even in the coldest weather. On the other hand, the conventional gasoline farm-type engine has electric ignition, which is frequently a source of trouble. It has a carburetor or mixer to be adjusted according to atmospheric conditions and quality of fuel, and finally the gasoline engine is very hard to start in cold weather.

Briefly enumerated, the chief advantages of the Hvid engine are:

a Mechanical simplicity
b Low fuel consumption at all loads
c Ability to start and run on any oil which will flow
d Low water-jacket losses
e No lubricating difficulties
f Constant compression
g Remarkable torque characteristics
h Absence of all electrical devices, hot bulbs and torches for ignition purposes
i Absence of all carbureting mechanism
j No carbon troubles.

The Hvid engine is of conventional four-cycle type, embodying the usual inlet and exhaust valves, timed to open and close as in any four-cycle engine. The compression pressure is carried to between 425 and 475 lb. per sq. in., which heats the compressed air to between 900 and 1000 deg. fahr. In the cylinder head there is a fuel-admission valve terminating in a small steel cup by means of which a preliminary explosion is made to force the fuel into the combustion space. Referring to Fig. 2, the Hvid cycle is as follows:

Suction Stroke. During the suction stroke pure air is admitted to the cylinder through intake valve *A*. Fuel valve *B* is opened in synchronism with intake valve *A* and some fuel flows into cup *C* out of hole *D* which is uncovered by the opening of valve *B* (the fuel enters cup *C* partly by gravity and partly by inhalation). The amount of fuel admitted is controlled by the metering pin *E*, which in turn is controlled by the governor. At the same time that the fuel is being inhaled into the cup, a small amount of fresh air is also drawn through an auxiliary air hole *F*, down past a fluted guide *G* into the cup *C*. At the end of the suction stroke, fuel valve *B* and air-intake valve *A* close, valve *B* sealing the fuel-admission hole *D*.

Compression Stroke. During this stroke all valves are closed and the air admitted to the cylinder on the suction stroke is compressed to about 420 lb. per sq. in., which raises its temperature to between 900 and 1000 deg. fahr. In other words, there is now a mass of highly heated air under high pressure in the combustion chamber and this rushes into cup *C* through small holes *H* near its bottom until the pressure in the cup is practically equal to the pressure in the combustion chamber. The conditions in the cup are now most favorable to "cracking" the oil, and as the oil cracks the lighter and more volatile components are detonated by the high temperature and the resultant high pressure within the cup forces the rest of the oil out into the air in the cylinder. The amount of fuel consumed in the cup per cycle is infinitesimal because there is only a very small amount of air present in the cup to support combustion.

Power Stroke. As the fuel in an atomized and vaporous state comes into contact with the heated air in the combustion space, very rapid combustion takes place and the pressure arising from it drives the piston.

Exhaust Stroke. As in any four-cycle engine, the exhaust valve opens and the products of combustion are forced out by the piston.

INDICATOR CARDS

Fig. 3 shows a series of indicator cards taken from the 8-hp. Hvid engine of Fig. 2, as well as one from a 20-hp. engine of the same type. Descriptions of these cards follow.

Card *A* is a no-load, stop-spring card which shows a slight vacuum during practically the entire suction stroke and figures approximately 375 ft. per sec. through the inlet orifice; at the same time it shows good volumetric efficiency. This vacuum is maintained intentionally for the reason that there is left in the injector cup, after the expansion and exhaust strokes, a slight residual pressure which interferes with the regular delivery of fuel by gravity. Dropping the suction pressure slightly below atmospheric removes this cup pressure, gives a slight pull on the incoming fuel and makes for close governing.

Card *B* is one taken from the inside of the injector cup with the main air-intake orifice not choked and shows a residual pressure in the cup even during the suction stroke of the engine. One of the greatest difficulties encountered in early Hvid engines of the farm type was consistent governing, and it was not until automatic inlet valves were discarded and the inlet-air velocity was maintained constant that good governing was possible. Card *C* is a full-load card and card *D* is a 25 per cent overload card.

Card *E* is a full-load card from an 8½-in. by 10-in. 20-hp. Hvid engine in which the ignition point is much more clearly defined than in the cards taken from the 8-hp. engine. There is no doubt that ignition takes places at relatively the same point on the smaller engines, but the speed of the smaller engines is so much higher that the ordinary indicator fails to show it.

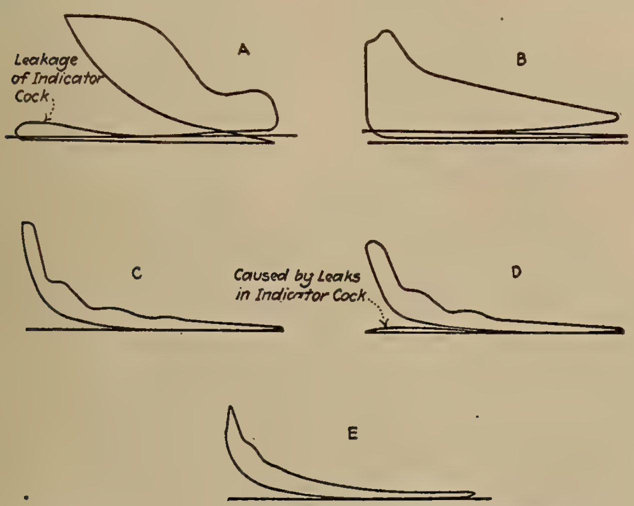


FIG. 3. INDICATOR CARDS TAKEN FROM HVID ENGINES

It is interesting to note the waves in the expansion line of these cards. These are typical of all cards taken from Hvid engines and are caused by the introduction of fuel into the combustion chamber in waves. At the moment when the preliminary combustion takes place in the cup, we have in the cup a pressure of approximately 800 lb., while in the combustion chamber there is a compression pressure of only 425 lb. Some fuel is consequently sprayed out of the cup into the combustion chamber by the attempt at pressure equalization. When the fuel comes in contact with the highly heated air in the combustion chamber, the pressure rises in the combustion chamber and falls in the cup until equalized; then no more fuel can get out of the cup until the piston moves forward and the pressure in the cylinder drops below that in the cup, when some more fuel is ejected from the cup. This is repeated until there is no more fuel left in the cup.

FUEL CONSUMPTION

The fuel consumption of small Hvid-type engines is very good, being in general on a par with Diesel engines of large size. If Diesel engines could be economically constructed in units as small as Hvid engines can, it is doubtful whether they would compare at all favorably in thermal efficiency with the small Hvid units on account of the mechanical inefficiency of the air compressors necessary to inject the fuel. In the comparative fuel-consumption curves shown in Fig. 4 the fuel economy of the Hvid engines as compared with two other types of the same size stands out very plainly, particularly at the lower fractional loads. The "hit-and-miss" gasoline test in Fig 4 was made by Professor Dickinson of the University of Illinois, the throttling-governor kerosene test by Mr. MacGregor of the Hercules Gas Engine Company, under the supervision of Government experts, and the Hvid-engine test by the writer under the supervision of Professor Roesch of Armour Institute. The engine used in each case was a 5¾-in. by 9-in., running 450 r.p.m. and rated at 8 hp.

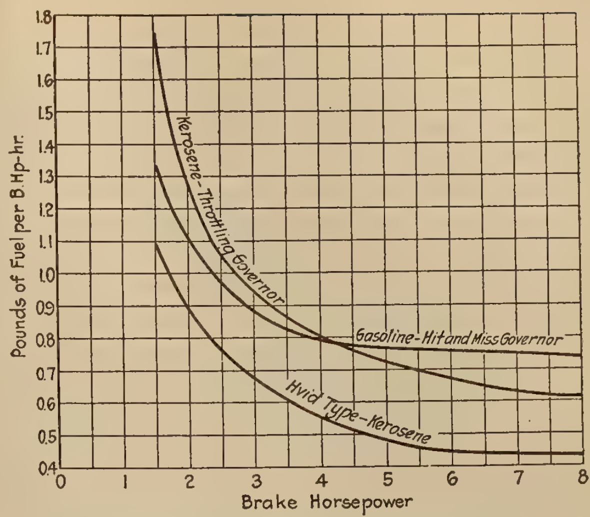


FIG. 4. COMPARATIVE FUEL CONSUMPTION CURVES OF 5¾×9 IN FARM-TYPE ENGINES OPERATING ON DIFFERENT PRINCIPLES

The fuel-consumption curve of the small 3-in. by 4½-in. Hvid engine shown in Fig 5 is particularly interesting because this engine, running at 1100 r.p.m. normally, is the first relatively high-speed engine of this type built. When it was first designed the writer was very skeptical as to the results to be expected from it, because, owing to the high speed, it was natural to suppose that trouble would be encountered with the time element necessary for the introduction of fuel into and ejection out of the cup; but it was found that this little engine could be run at speeds as high as 1500 r.p.m. without any apparent interference with the perfect operation of the Hvid principle. In fact, the faster it was run the better the results. Based on its performance several engineeers connected with the production of Hvid engines raised the normal r.p.m. of their engines with very beneficial results.

Professor Roesch also supervised other tests made to determine the entropy diagram and the heat balance, while Mr. H. C. Knudsen made tests for torque. It is worth while to record here the results of these tests.

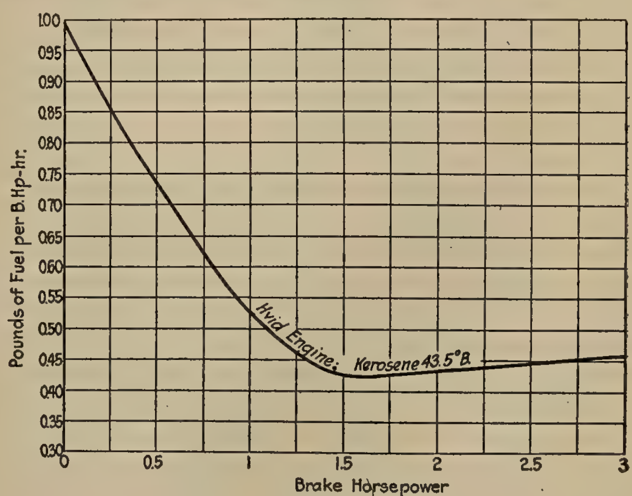


FIG. 5. FUEL-CONSUMPTION CURVE OF A 3×4½ IN. HVID ENGINE

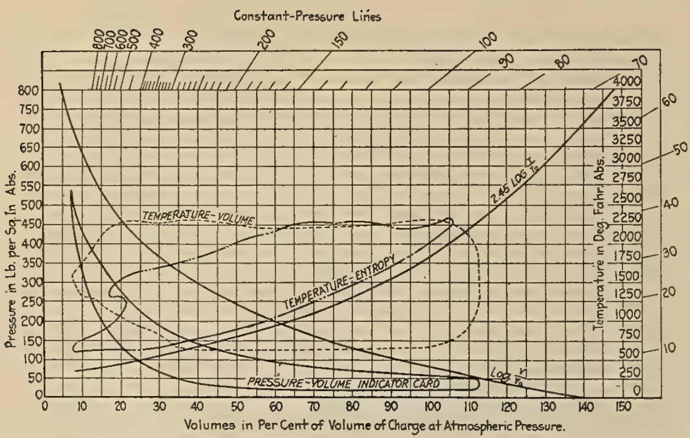


FIG. 6. VOLUME-TEMPERATURE DIAGRAM FOR A 5¾×9 IN. SINGLE-CYLINDER HVID KEROSENE ENGINE

Entropy Diagram. The entropy diagram, shown in Fig. 6, was plotted from a pressure-volume indicator card taken from a 5¾-in. by 9-in. single-cylinder Hvid-type engine running at 450 r.p.m. and using kerosene as fuel. This diagram is submitted because it shows the general temperature characteristics, which are quite different from those in an explosive gasoline engine. It is interesting to note the low maximum temperatures, 2300 deg. fahr. abs., as compared with the maximum temperatures for gasoline engines, which frequently run as high as 3000 to 3500 deg. fahr. abs., and also the sustained temperature in the Hvid engine throughout the working or expansion stroke. At first glance it might be argued that this sustained temperature would be harmful because of undue heat losses to the water jackets, but since the water-jacket losses are low and the thermal efficiency of the engine is remarkably good, the writer believes that combustion in the Hvid engines takes place in the form of zone burning and that the cylinder walls are more or less insulated from the high temperatures of combustion by a layer of air which is not burnt until near the end of the stroke.

Heat Balance. This test gives the mechanical efficiency and the thermal efficiency for both brake and indicated horsepower. It was made upon a 5¾-in. by 9-in. single-cylinder Hvid engine which was flexibly connected to a Sprague electric cradle dynamometer by means of two "Spicer" universal joints. Engine speeds and fuel weights were obtained by means of electrically operated appliances. Arrangements were also made for determining the jacket-water loss and the sensible heat of the exhaust gases (calorimeter method). The developed and friction horsepower were determined by means of the dynamometer. Indicator cards were also taken, but because of the probable errors due to the high pressure involved and the comparatively high speed of the engine, these cards were used merely to study the valve settings and general events of the cycle, and not for indicated power measurements. The engine was operated under various loads and speeds with various adjustments of fuel supply, compression and cup design. The final setting was made with a compression of 390 lb. per sq. in.

Test runs, curves for which are shown in Fig. 7, were conducted at various loads from a maximum to about one-eighth of maximum load, and readings were taken to determine the following:

1 Friction horsepower (electric-dynamometer method)
2 Brake horsepower (torque and speed)
3 Jacket-water loss
4 Sensible heating in the exhaust (calorimeter method)
5 Loss due to radiation and incomplete combustion (by difference)
6 Fuel consumption (lb. per hour).

Items 1 and 2 are determined directly from dynamometer readings; items 3 and 4 are calculated from observed temperatures and weights; item 5 is determined by difference; and item 6 is obtained from direct measurements. The heat value of the fuel expressed in B.t.u. per lb. of kerosene is calculated from the following accepted formula:

$$\text{B.t.u.} = 18{,}440 + 40 \times (\text{deg. Baumé} - 10)$$

and is 19,740 B.t.u. for the quality of fuel used in the test runs.

Torque. In Fig. 8 are shown some of the torque characteristics of the Hvid engine. When a gasoline engine of conventional design is overloaded so that the speed drops beyond a certain point its torque drops rapidly, because a certain velocity of air must be maintained through the carburetor to pick up and vaporize the fuel and carry it into the cylinder; but in a Hvid engine, since the introduction of fuel into the cup and into the cylinder is not dependent upon the velocity of the air taken in, as the speed drops, due to overload, more fuel is admitted than at normal speed, because the time element for the introduction of fuel is lengthened and the engine consequently shows remarkable "hanging-on" characteristics.

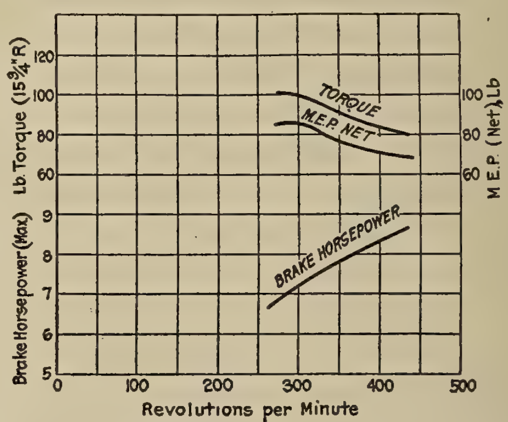


FIG. 8. BRAKE-HORSEPOWER AND TORQUE CURVES FOR A 5¾ X 9 IN. SINGLE-CYLINDER HVID ENGINE

Under these conditions it is very wasteful of fuel without a doubt, but there are certain conditions where this "bull dog" characteristic is desirable even at the expense of fuel economy. Mr. Knudsen states that these values were actually obtained on the test block but that he is of the opinion that under actual operating conditions the torque should not be allowed to climb quite so high for the lower speeds, the reason being that the engine smokes badly and takes too much fuel at speeds below 450 r.p.m. It would seem to be better practice to vary the opening of the fuel valve with the speed of the engine, so that a curve could be plotted, giving maximum torque at different speeds with a uniformly clean exhaust.

In conclusion, the writer would say that while the Hvid engine has by no means reached its ultimate state of development, it nevertheless possesses a number of wonderful characteristics which ought to attract many internal-combustion engineers by the possibilities they hold out of helping to solve some of our fuel problems.

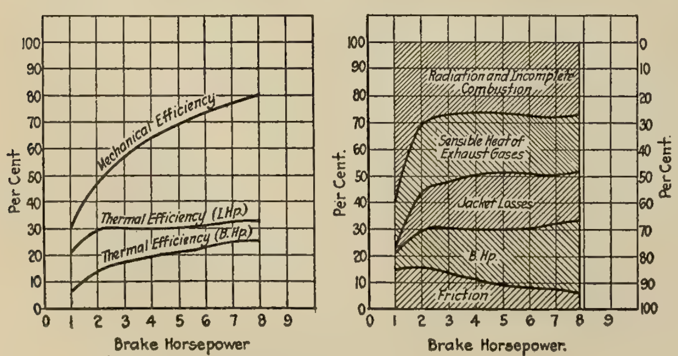


FIG. 7. HEAT BALANCE AND EFFICIENCY CURVES FOR 5¾×9 IN. SINGLE-CYLINDER HVID ENGINE

Science and National Progress

Edited by a Committee of the National Research Council

Dr. Vernon Kellogg, Chairman, Dr. R. M. Yerkes, H. E. Howe

The National Research Council is a coöperative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

THE National Research Council is a group of scientific, technical and business men organized under the Congressional charter of the National Academy of Sciences, with the coöperation of our National scientific and technical societies, educational institutions, the industries, and independent specialists. The Council was established in 1916, to coördinate the research facilities of the country for work upon war problems, and in 1918, by executive order of the President of the United States, it was reorganized as a permanent body.

While enjoying the hearty coöperation and support of the various Government departments, the Council is not a Government bureau, nor is it financed by the Government. Its duty is to promote research, both scientific and industrial, and to encourage the training workers capable of engaging in research and applying its results. It is to this organization and its work that we wish to introduce the readers of the SCIENTIFIC AMERICAN MONTHLY Magazine.

It has been the history of the race that many of our most valuable lessons have been learned as a result of the stimulation derived from such an upheaval as a war, and, frequently, the greater the conflict the greater has been the ultimate good which has come from it. In a discussion on "The National Importance of Scientific and Industrial Research," by Dr. George E. Hale in Bulletin No. 1 of the National Research Council, this point is emphasized and the following quotation from de Tocqueville is cited:

"When a violent revolution occurs amongst a highly civilized people, it cannot fail to give a sudden impulse to their feelings and ideas. This is more particularly true of democratic revolutions, which stir up at once all classes of the people, and at the same time beget high ambitions in the breast of every citizen. The French made surprising advances in the exact sciences at the very time when they were completing the destruction of the remains of their former feudal society; yet this sudden fecundity is not to be attributed to democracy, but to the unexampled revolution which attended its growth."

Perhaps it may have been due to the gigantic scale upon which the late war was conducted, or perhaps not, but whatever the reason the extraordinary degree to which coöperation between all classes and interests was secured, was one of the outstanding features of the war activities, and one of the lessons which we must not forget. When it is remembered that the industrial problems of peace are in a large measure the same as those of war, although with a somewhat different emphasis, the importance of continued coöperation is difficult to overestimate. This is particulary true in the case of pure and applied science upon which our continued progress annd property depend. That this view is universally held is amply illustrated by the world-wide effort to organize science. With this movement some of our foreign friends were identified before the formation of our own National Research Council, but in these cases there is an essential difference in that the foreign organizations have been developed under the auspices and control of their respective governments and have been made a part of the government organization.

In Great Britain as early as July, 1915, a committee was appointed by the Privy Council for the purpose of directing the application of any money provided by Parliament for the organization and development of scientific and industrial research. This committee appointed an advisory council and in December, 1916, the work of the committee first appointed was established under a separate Department of State, which has since been designated "The Department of Scientific and Industrial Research." This department is responsible to a minister of the Cabinet, and has been intrusted with the expenditure of some five million dollars to stimulate and support, as well as coördinate, scientific investigation in Great Britain for the benefit of the Empire. The work done under the direction of the advisory council and the department during the war was indispensable to the success of the military establishments of the Empire, and the effort of the department is now directed toward the formation of coöperative research associations among those concerned with the same class of materials, the encouragement of research workers, and the organization of national research under which classification are to be found problems, the solution of which belongs more to the Government than to any private group. Among such investigations may be noted the question of mine-rescue apparatus, researches with reference to building materials including home-grown timbers, and extensive researches relative to fuel and food, and to industrial fatigue.

As for the research associations established by industries, eight have been incorporated, a like number have been approved but not licensed as yet, and a number of others are engaged in completing their arrangements and drafting articles of association.

In addition to these efforts on the part of Great Britain herself, the Dominions, especially Canada and Australia, have made substantial progress in like organizations while plans are well under way for similar activity in India, New Zealand, and South Africa.

Japan has also established a National Laboratory for Scientific and Industrial Research, with a fund of two and one-half millions of dollars for use during the next ten years.

Italy has prepared to continue the work undertaken in 1916 by the Office of Inventions and Research which was then created under the Department of the Ministry of Arms and Munitions. The Italian National Research Council is now in progress of formation and will conduct its work under seven divisions of science.

Science for years has assisted in the organization of many lines of effort, but in so doing has neglected to organize itself. The National Research Council represents a unique effort at thorough organization of American science, and the success which resulted from such organization and coöperation during the war gives every reason to believe that the National Research Council will be even more successful under peace conditions, than it could be during the exciting times of war. The duty of the National Research Council is the promotion of research, both scientific and industrial, and in the terms of the executive order issued May 11, 1918, by the President of the United States, its functions are as follows:

"In general, to stimulate research in the mathematical,

physical, and biological sciences, and in the application of these sciences to engineering, agriculture, medicine, and other useful arts, with the object of increasing knowledge, of strengthening the national defense, and of contributing in other ways to the public welfare.

"To survey the larger possibilities of science, to formulate comprehensive projects of research, and to develop effective means of utilizing the scientific and technical resources of the country for dealing with these projects.

"To promote coöperation in research, at home and abroad, in order to secure concentration of effort, minimize duplication, and stimulate progress; but in all coöperative undertakings to give encouragement to individual initiative as fundamentally important to the advancement of science.

"To serve as a means of bringing American and foreign investigators into active coöperation with the scientific and technical services of the War and Navy Departments and with those of the civil branches of the Government.

"To direct the attention of scientific and technical investigators to the present importance of military and industrial problems in connection with the war, and to aid in the solution of these problems by organizing specific researches.

"To gather and collate scientific and technical information at home and abroad, in coöperation with governmental and other agencies, and to render such information available to duly accredited persons."

In order to carry out this important program, the membership of the National Research Council has been chosen with a view of rendering the Council an effective federation of the principal research agencies in the United States concerned with the fields of science and technology. The work has been organized along division lines, the divisions themselves being of two classes: first, those dealing with the more general relations of the Council, and, second, those concerned with related branches of science and technology.

There are six divisions in the first group.

The Government Division.—Chairman, Dr. Charles D. Walcott, secretary of the Smithsonian Institution, in which are represented the various scientific bureaus and groups of the Government. This division will have very important work to perform in obtaining an even greater degree of coöperation in Government and scientific matters than has heretofore been possible and through its conferences and discussions many new methods of attack and entirely new subjects for research may result.

Division of Foreign Relations.—Chairman, Dr. George E. Hale, director of the Mt. Wilson Solar Observatory and foreign secretary of the National Academy of Sciences. This division includes representatives of the Department of State, of the National Academy of Sciences, The American Association for the Advancement of Science, and the American Philosophical Society. The division is further strengthened by having as a member the Hon. Elihu Root, former Secretary of State. There are a great many problems in fundamental science which are international in their scope and of such character that they do not properly come under the divisions of science and technology. These questions will have the attention of the Divisions of Foreign Relations which, through its connections abroad, will be in a position to maintain close contact between investigators in similar fields in those countries with American workers, to their mutual advantage.

Division of States Relations.—Chairman, Dr. J. C. Merriam, of the University of California. This division has for its purpose at present the study of the relationships of the various agencies within a State which are concerned either with the development or the application of scientific knowledge. In the work of certain committees organized by State Councils of Defense to meet war conditions there is much to indicate the value of concerted action in pushing forward scientific investigations upon matters affecting public welfare. It is hoped that in many cases State committees can be organized for the purpose of bringing about more complete coöperation between the various State scientific bureaus, the scientific departments of its colleges and universities, the scientific aspects of its industries and matters of conservation, as well as of public health. It seems obvious that such committees should regard the needs of a State and its resources in men, institutions, and materials with which to meet these needs, from a wide angle of view and with a long reach into the future. The division is now placing its plans before those who are interested both in the progress of knowledge and the fundamentals of science, and the application of this knowledge to all phases of public good, in the hope that it may have the benefit of consideration from many points of view and thereby be able to associate its activities so as to accomplish as much as possible. The division reaches a great diversity of interests through its membership.

The Division of Educational Relations.—Chairman, Dr. Vernon Kellogg, of Stanford University. This division bases its work upon the principle that a fundamental factor in the advancement of learning and civilization, insofar as this is dependent upon education, is the ability to conduct research progressively. Inasmuch as the large majority of research workers are to be found in the universities and colleges upon which we must also depend for the development of new workers and that it is on these institutions that we must depend for the development of new workers, it is incumbent upon us to assist in creating the atmosphere and the opportunity favorable to the stimulation and activity of scholars and those are to become scholars. The membership includes officially appointed representatives of all the universities associations and the United States Bureau of Education, together with a number of members at large, among whom may be mentioned Abraham Flexner, secretary of the General Education Board, H. S. Pritchett, president of the Carnegie Foundation for the Advancement of Teaching, and Herbert Hoover.

It is felt that we have reached a stage in the progress of research where we may well pause to consider what the conditions are which at present hinder research in American colleges and universities, or which, if more fully developed, would permit of increased productivity in research. One of the first activities of the Division of Educational Relations will be to seek the coöperation of institutions of higher education in a study of these conditions. This study has already been actively begun.

Division of Industrial Relations.—This division has for its chairman, Dr. John Johnston, of Yale University, and its membership includes representatives of Government bureaus, of the Naval Consulting Board, industrial research laboratories, chemists, engineers and business men. The division endeavors to stimulate a better appreciation of the necessity of applying all the science at our command to our industrial problems and to support and engage in researches in fundamental science, in order that there may be more knowledge without which the solution of many production and process problems will be impossible. This division has carefully considered the present situation with respect to industrial research and has launched its activities with a proposal to organize an association for alloys research, which association will be made up of both consumers and producers of alloys, who can jointly support research on the fundamentals of pure and alloyed metals. In several special branches of industry progress awaits determination of chemical and physical constants, with respect to the composition of metallic mixtures. The field is so broad that no one concern would be justified in doing all of the work as thoroughly and as fundamentally as is needed. At the same time, the advantage to the respective members of the association will in the end depend upon their ability to apply the data thus secured, so that the proposed investigations present an unusually attractive opportunity for coöperative effort into which no spirit of commercial competition need enter. The division has prepared a tentative outline for the formation of such an association and, following a discussion with those most interested, will soon be inviting

manufacturers to become members on a basis that seems certain to make unusual returns for the expenditure. The division has also initiated work with respect to research in the great cotton industry, and in coöperation with the World Cotton Conference, held in New Orleans in October, 1919, plans to assist the various branches of the cotton industry to unite on some research policy and to engage actively and consistently in the prosecution of research. A start has already been made by several of the associations in the cotton trade, but there seems to be an opportunity to correlate these movements and for this purpose the Chairman of the National Research Council and the presidents of the National Association of Cotton Manufacturers, the American Cotton Manufacturers' Association, and the American Society for Testing Materials have been asked to join in the appointment of a small committee which will survey the work in America, outline problems which should be undertaken immediately, suggest methods of attack, and prepare a budget for the consideration of the various associations which must join in financing and organizing the specific work. This question has an international phase, for cotton is a commodity of universal importance and some features of the problems must be considered in other cotton-growing and consuming countries. It is contemplated that eventually research associations in the cotton industry will undertake various special problems simultaneously for the good of all and for the direct benefit of the race.

Special attention is drawn to the American Association of the Baking Industry and its recent accomplishment in establishing an American Institute of Baking, for which the National Research Council is about to appoint an advisory committee. The division of Industrial Relations has had some part in assisting the association in its work and it is a pleasure to be able to say that the baking industry is about to begin, through its Institute, a program of applied science in which the people at large are directly concerned. In addition to research into the fundamentals of the baking industry, there will be specialists available for work upon problems of production and a center will be established which will greatly assist in directing the education of those now engaged or about to engage in the baking industry. Problems of nutrition—the possibility of producing an equally nutritious and palatable loaf at a lower price, the best method of handling various flours and the possibility of using the many food products which science is constantly improving without lowering the actual value of the baker's product, indicate but one or two of the important problems which face the Institute. Dr. H. E. Barnard for a long time associated with the Indiana State Board of Health and Federal Land Administrator of Indiana during the war, becomes the director of the institute.

There are many other special fields in which an effort will be made to have research undertaken on a more extensive plan, either in the laboratories of the industries, in existing laboratories both of the university and commercial type or in new ones to be established in special instances.

Research Information Service.—Dr. R. M. Yerkes, formerly of Harvard University, is the chairman of this division. The service maintains a large permanent staff and is really a clearing-house and information bureau for scientific and industrial research. The service seeks to promote research by supplying individuals or institutions with such information, or to advise concerning research projects, the location of special equipment, an indication of methods of attack, the problems now being solved or proposed for solution, or with published results, to the end that coöperation may be encouraged, duplication lessened, support increased, and the exchange of reports concerning progress in related investigations promoted. By increasing the efficient distribution of research effort, it is certain that greater wisdom may be exercised in the choice of problems and it is one of the objects of the service to assist in reaching this desired end. This is, of course, a large program and for the present the service seeks to develop, as its principal mechanisms of exchange, a carefully cross-referenced catalog of current scientific investigations, a similar list of research laboratories, a list of investigators with suitable cross-references, a catalog of sources of scientific and industrial information, and such bibliographies, digests, etc., as are incident to this work. Obviously, to accomplish this purpose, the Research Information Service must have the coöperation of all investigators and such cooperation is invited. The extent to which directors of laboratories and investigators generally can give their assistance will determine the success of this important undertaking, and there is every reason to believe that those who are willing to assist will receive far more than they contribute. This is not an attempt to centralize and control scientific work, but an effort to be of greatest possible service.

At the moment, several important publications are in preparation or are on the press, the first being a bulletin on "The National Importance of Scientific and Industrial Research" by a number of authors. "Research Laboratories in Industrial Establishments of the United States" is the title of another bulletin soon to go to press, in which the industrial research laboratories, their location, special fields of work, size of organization, unusual equipment, etc., will be tabulated and cross-indexed for the benefit of the industries and those concerned in their application of science.

The divisions of the second group are those of science and technology, seven in number. The organization of work of this character has been difficult since in any effort of this kind careful precautions must be taken to do nothing which might discourage individual effort or initiative. That many of the notable advances in science have been made by individuals, many of whom work more or less in a state of isolation, is well recognized, but it is equally clear that in many instances such a genius, if provided with proper assistance, will accomplish far more than would otherwise be possible. It is believed that coöperation can accomplish this, and the situation is well expressed by the following paragraph from the correspondence files of the Council:

"Without the personnel, without the laboratory and the great factory facilities, I become but a single, isolated unit and worth but a few per cent of my value as part of that developed organization."

In practically all cases, any division or committee activity has necessarily been preceded by a careful survey of the special field in which it is working. The object first of all is to become acquainted with the present status of investigations in order to determine where the gaps and missing links are so that new effort may be directed toward filling them. Such conferences and discussions have also served to bring together those interested in various phases of a common problem, and this always results in much benefit to those concerned. The Council in all its work seeks to avoid duplication of any work well organized and in good hands. In many cases, its divisions have been able to encourage those now engaged upon the solution of some problem, have suggested new lines of attack, have been able to locate special apparatus and sometimes to increase the number of workers in a particular field or to secure the interest of new workers in checking over the work, duplicating some of the experiments for confirmation and preparing the data for publication. In some instances duplication is unnecessary, while in others it is highly desirable to conduct similar experiments in different laboratories to reduce errors due to personal equation, and likewise to conduct the experiments under the different conditions which naturally exist in various laboratories.

Division of Physical Sciences.—Chairman, Dr. C. E. Mendenhall, of the University of Wisconsin. The American section of the International Geophysical Union has been a committee of this division. The American branch of the International Astronomical Union is undergoing reorganization following

successful activities as a committee of this division, while steps are about to be taken to organize an American branch of the International Mathematical Union, which will have important work to perform. A number of research committees to study conditions in various fields of the physical sciences are in process of formation, and at present 15 committees are devoting attention to such important subjects as "X-ray Spectra," "High Vacua," "Theory and Practice of Wireless," "Acoustics," "High and Low Temperatures," "Aeronautics," "Magnetism," and "Spectroscopy." The division is carrying on coöperative work with the Division of Chemistry and Chemical Technology on the tables of critical data, and also in the administration of the research fellowships, which will be mentioned below.

Division of Engineering.—Chairman, Dr. C. A. Adams, of Harvard University. This important division has been organized with the coöperation of the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Mining Engineers, the American Society of Civil Engineers, the American Society for Testing Materials, the Society of Automotive Engineers, the American Society of Illuminating Engineers, the Western Society of Engineers. Its personnel is composed of officially appointed representatives of these societies, together with 12 members at large. The Engineering Foundation is represented by five members, one of whom is the chairman of the Engineering Foundation. When one considers the broad field of engineering, especially as represented by the societies indicated above, it is apparent that this must be one of the most active divisions of the Council. So far, its work has proceeded under the direction of some 20 special committees, and the problems upon which study is being directed are all of immediate importance to industry at large. Its committee on pyrometers has made a report in the form of a symposium at the Chicago meeting of the American Institute of Mining and Metallurgical Engineers, and more than 90 important papers were presented. The committee on fatigue phenomena has in progress very interesting work from which may come practical methods for determining in advance when the stresses to which metal is subjected in use have carried it nearly to the breaking point, so that replacements and repairs can be made in advance of annoying or even disastrous breaks. Some of the other important subjects are: "Pulverization." "Standardization of Bearing Metals," "Uses of Alloyed Steels," "Welding Research," "Improvements of Metals at a Blue Heat,' "The Heat Treatment of Carbon Steel," "The Elimination of Inclusions from Steel" and "Electric Insulation."

Division of Chemistry and Chemical Technology.—Chairman, Professor W. D. Bancroft, of Cornell University. In the organization of this important division the American Chemical Society, the American Electro-Chemical Society, the American Institute of Chemical Engineers, and the American Ceramic Society have been active. The special duties of this division seem to fall into three special phases: *first*, securing coöperative research on fundamental things; *second*, the suggestion and assignment of special research problems; and, *third*, the bringing together of men in different fields. It is thought that often the research student may as well be assigned some problem which will supply missing data in some broad plan rather than to undertake some other line of work which may be just as important in itself but of less consequence at the moment because it is not correlated with work that has been done. Hence, lists of suggested problems are being compiled with the purpose of suggesting them to those who are concerned with the direction of graduate students and others interested in research. In this division there is a committee on explosive investigations, of which Dr. Charles E. Munroe is chairman, and the work they are undertaking has the direct support of the Departments of War and Navy and the Bureau of Mines of the Department of the Interior. The activities of this special committee will be discussed in greater detail in subsequent reports. Other committees, all including men in the forefront of their fields, are: a committee on synthetic drugs; one on the chemistry of colloids; another on the thermal properties of explosive materials; a committee on caramics research; another on sewage disposal; and another on chemical journals. In addition, a committee on the teaching of organic chemistry is being organized, with the hope that it will be able to make suggestions that will improve the teaching of organic chemistry in our universities. It seems important that more stress should be laid on qualitative organic chemistry, a field which has not thus far had the attention it deserves.

Naturally, the Division of Chemistry is called upon to coöperate with many other divisions. Thus, it is interested with the geologists in developing a theory of sedimentary rocks. The applications of colloid chemistry are of direct interest to the biologists, and there are many points in common with the physicists. A problem of unusual importance is the production of different kinds of pure, rare sugars by means of which various bacteria may be identified and differentiated, which is in the field of medicine. The Division of Chemistry is directly concerned in the National Research Fellowships, to be referred to later.

Division of Geology and Geography.—Chairman, Dr. E. B. Mathews, of Johns Hopkins University. While geological and geographical matters have been pretty well organized by various State and Federal agencies, it has become evident that the Division of Geology and Geography can do a great deal of constructive work in surveying the entire field and attempting to have certain gaps in the information supplied by means of new researches. The division is also in a position to act as a clearing-house for information and to bring together men widely separated geographically, who would each profit by knowing the activities of the other, the direction his work is taking, and the present status of his investigation. In some cases, work on a problem has ceased when some individual has been compelled to drop it, and frequently it is well worth while for another investigator to take up the thread and endeavor to solve the problem. The aim of the division is to work with existing organizations and to support their efforts rather than to establish a new agency of research which might have conflicting interests.

Division of Medical Sciences.—Chairman, Dr. H. A. Christian, of Harvard University. To indicate the many lines in which the Division of Medicine is interested would involve a discussion too lengthy for this present announcement. Plans are being made for investigation of medical problems in industry at the suggestion of the Engineering Foundation; also certain activities in neurology and psychiatry are under consideration. Work on intestinal parasites, anaerobic bacteria, and studies of pacific therapy and allied problems, in coöperation with chemists, are being outlined. There are a number of coöperative investigations which are to be undertaken with the physicists and questions of publication in the biological and anatomical fields, upon which work is being done. There seems to be an opportunity for constructive work in international indexing, abstracting, and the critical review of scientific literature, as well as a possibility of establishing a central bureau of information regarding technical methods which are applicable to the medical sciences.

While many of the divisions are interested directly in the International Research Council and its activities, none is more concerned than the Division of Medical Sciences, and great expectations are held for the ultimate success which will attend international effort in the suppression of communicable diseases and epidemics in their earliest stages in the areas from which they are believed to spread.

Division of Biology and Agriculture.—Chairman, Dr. C. E. McClung, of the University of Pennsylvania. This important division has a number of projects in the hands of several committees, some of which work in close coöperation with other divisions of science and technology. Some of these commit-

tees have been the outgrowth of similar ones in the Council during the war organization and work begun then can be profitably carried on under the present organization. Typical committees are those on food and nutrition and on forestry. In them are representative leaders in the sciences and their projects are of vital concern to the public. The Committee on Food and Nutrition is divided into a Subcommittee on Human Nutrition and a Subcommittee on Animal Nutrition, with special reference to animals of agricultural importance. The object here is to promote scientific research upon food and nutrition problems and to bring about closer relations between the two fields of work represented by the subcommittees. A study of the economics of nutrition and its national and international phases as distinguished from personal nutrition, is to be undertaken. Efforts will be made to promote coördination of both American and foreign research and to conduct authoritative propaganda work in the interest of better nutrition. The funds which have been intrusted to the National Research Council are for the support of its general organization, so that any special undertaking must be financed independently. Therefore, an appeal will shortly be made for additional funds with which to carry out the work of the committee above mentioned and it is encouraging to be able to say that one of the large food companies has already entered into an arrangement to contribute to the support of the researches proposed.

The Committee on Forestry appeals to a great number of industries which will be directly benefited by the work it has in hand. The forest problems of the nation are so large that some such coöperative body is essential to their early solution, and without the data which cannot be obtained otherwise than by such research studies, it is obviously impossible to formulate a rational forest policy for all parts of our country. One of the problems upon which this committee will work is systematic measurements on thousands of representative areas well-distributed over the forest regions of the United States to determine how rapidly our second-growth timber is producing the amount and kinds of merchantable timber which our industries will require in the not distant future. The solution of this problem is more difficult than appears on the surface, for it involves the succession of vegetation on cut-over land and is closely allied with another problem, which is the standardization of lumbering practice and forest treatment, to insure the self-perpetuation of forests.

It is well known that a certain type of forest does not necessarily follow itself but is often succeeded by an entirely different type of vegetation, sometimes of a shrub character. We therefore must study the effects on the second-growth of the different methods of cutting the old stands, and of different ways of handling the land after the cutting has been made. The proper use of fire must be determined, for in some instances the data indicate that the use of fire is beneficial in preparing the new seed-bed. We need to know more about the number and kind of seed trees which should remain per acre, and the effect of grazing upon the new stand. If a lumberman is to hold his cut-over lands until the new forest becomes of commercial value, it is essential that some method be devised whereby the land can be made to earn at least enough on the investment to pay the taxes and overhead expenses, and it seems possible that grazing, which involves the selection of the best forage grasses for the purpose, may prove to be the solution.

We also need to know more concerning the correlation between the biological factors and the physical, mechanical, chemical, and structural qualities of timber. All of these questions and many others involve coöperation on the part of federal and state agencies as well as a large number of individual workers. Funds will be required to carry out the work which will begin with a careful tabulation and study of present information and work in progress, in order that those agencies now in the field may be encouraged to supply the missing parts and new agencies have their efforts directed into the untilled fields from which additional data will be secured. This type of work directly concerns not only the lumber interests but those for whom wood is a raw material. In this list may be included the makers of wheels, handles, boxes, veneers, and the many specialties into which particular kinds of wood enter.

Division of Anthropology and Psychology.—Chairman, Dr. W. V. Bingham, of the Carnegie Institute of Technology. This division is just completing its organization, but something of what may be expected can be forecast from the activities of its predecessor in the war organization.

The tests of mental alertness for enlisted men, providing for those characteristics which are important in the aviation service, were prepared by this division, and the contributions of psychologists to the study of qualifications for flying and the psychological effects of high altitudes were of the first importance. Aid was rendered to the Division of Psychology of the Medical Department of the Army in administering mental tests to officers and enlisted men. The rating of soldiers according to mental alertness or degree of intelligence aided materially in the proper utilization of various grades of intelligence, and more than 1,700,000 individuals were examined. It was demonstrated that psychological methods could be devised and adapted to assist in selecting and training observers and scouts, and it was largely due to the efforts of the psychologists that a morale branch of the general staff was established and facilitated by the War Department. These military activities also extended to the selection of suitable look-outs for merchantmen, the selection of men for special assignment in gunfire squads, and to serve as listeners. It is a source of gratification that the methods devised by the division are proving of great assistance to those worying independently in the classification of workers. This sort of work can be profitably extended to study of school children and others, with the result that special instruction can be undertaken in time and much lost effort saved.

It will be seen from the above that all the sciences are more completely represented in one central organization to a greater degree than has ever before been attempted in this country, and this alone is very important, for remarkable achievements have always resulted from the cross fertilization of the sciences.

While the successful research worker must be a specialist in a narrow field, he often finds the application of methods and apparatus of another science to be to his undoubted advantage, and any man is broadened by coming in contact with those having principal interests quite different from his own.

National Research Fellowships.—It is not enough merely to encourage research; we must also help to provide men to engage in fundamental research and it is, therefore, very fortunate that the Rockefeller Foundation has provided a fund of $500,000 to be expended during the next six years under the direction of the National Research Council for National Research Fellowships in Chemistry and Physics. These fellowships have for their purpose the confirmation of exceptional young men in pure research in these sciences and the increase in the amount of available knowledge secured by making it possible for the exceptional research worker to remain in his field devoting himself to fundamentals at the time when he can accomplish most, namely, immediately following the receipt of his doctor's degree. These fellowships are unique in that the fellow may choose not only the subject of his research but the place at which he will study, and the Council undertakes to encourage research in the university chosen by arranging for suitable facilities so that the work may be properly carried out.

The National Research Council, in order to perform its duties, must be kept free from undue political and industrial influences. It therefore derives its support from a wide, democratic backing, and it is confidently believed that its results will be such as continually to win even wider support.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

BLOWERS FOR AERO ENGINES.

Description of blowers built in Germany for use in supercharging aircraft engines at high altitudes.

The blowers are of the centrifugal type. Three or four stages are directly driven off the engine shaft, suitable provision being made to prevent torsional oscillation. The delivery is regulated by throttling the air intake of the blower. The carburetor has to be compensated for variations of air pressure in the usual manner. The speed of rotation is very high—10,000 to 11,000 r.p.m., and special steels are used for the rotors. The weight of a blower complete with fittings suitable for an engine 260 hp. and capable of reproducing ground-level conditions up to 15,000 ft. is 125 lb. The power consumed is about 25 hp.—*W. G. Noack, in Flugsport*, Sept. 19, 1919, abstracted through *The Technical Review*, Oct. 28, 1919.

GASOLINE ENGINES FOR STREET-RAILWAY CARS.

Discussion of the respective merits of the two types of propulsion for street-railway service. The writer claims that while the gasoline motor is excellent for certain classes of service such as automobile and truck work, it is not suitable for street-railway cars.

The electric motor is almost ideally suited for street-railway service. Its speed-torque characteristics meet the requirements as the electric motor has the enormous starting torque of the over-load capacity and flexible speed characteristics necessary to give the rapid acceleration and different speeds for street-railway service. In point of reliability it also stands very high and its cost of maintenance, depreciation and power are all relatively low.

The gasoline motor can make street cars run, but its speed-torque characteristics are not well adapted for the work. Thus, it absorbs from 25 to 30 per cent of its normal amount of power when running idle. It has no starting torque and very little torque at low speeds. Gear ratios help to balance this weakness, but at best the gasoline motor would give a very poor acceleration for a street car unless it were very much overmotored.

The reliability of the gasoline motor is also claimed to be less than that of the electric motor.

As regards costs, it is claimed that they would be higher for gasoline cars because the cost of maintaining the transmission on motor trucks and motor buses is very high. It is also claimed that the life of a gasoline motor is shorter than that of an electric motor.

It may be well to call attention, in this connection, to the fact that whenever the author speaks of motors for street-railway service he compares the electric motor with the airplane-type gasoline motor, which is, of course, the very last thing that could be thought of for applying in street-railway service. —*N. W. Storer*, in *Aera*, October, 1919, pp. 375-378.

DETERIORATION OF NICKEL SPARK-PLUG TERMINALS IN SERVICE.

The most commonly used material for terminals in spark plugs is commercial nickel wire containing about 97 per cent nickel, the remainder being manganese, cobalt, iron, copper and minor impurities. The peculiar type of deterioration that occurs in these nickel terminals during the service life of the spark plug was recently brought to the attention of the Bureau of Standards, the present paper giving the main results of the investigation.

It has been found that the deterioration of the central terminal was quite negligible compared to that of the side terminal or terminals. These latter wires had developed, in service, transverse cracks that in many cases were as sharp and definite as a knife cut. After a separation occurred the bridge widened by loss of material from ends of the fractured wires until a gap of as much as one centimeter often resulted. The fragments of the deteriorated wire terminals removed from the spark plugs were found on the whole to be rather ductile and stand several sharp right-angle bends before breaking. The extreme end portion immediately adjacent to the break, however, was brittle and broke readily when an attempt was made to bend it.

The examination of the central terminal showed that a change of the same character as occurred in side terminals had taken place in this one also, but to a far less extent.

The tests would indicate that variations in chemical composition such as occur in commercial nickel wire are not a determining factor in the deterioration of the wire in service. Terminals of nickel of relatively high purity were found to be attacked in the same manner as others of lower nickel content. Oxidation of the nickel does not appear as being of great importance in this connection, and the action of hot reducing gases, though somewhat greater than that of oxidizing, does not appear to be very great either.

It would appear that the main cause of embrittlement of the wire lies in the intense local heating by means of the electric spark, together with the sudden cooling, and that once the formation of transverse intercrystalline cracks has started the application of a relatively low stress to the hot wire is sufficient to fracture the wire.—*Henry S. Rawdon* and *A. I. Krynitzky*, in *Bulletin of the American Institute of Mining and Metallurgical Engineers*, August, 1919, pp. 1323-1350.

COPPER DIFFUSION THROUGH CAST IRON.

When a malleable-iron bar packed in copper oxide packing and annealed at 1,000 deg. cent. was taken from the furnace it was found that the copper oxide was reduced to metallic copper, which latter was melted and penetrated into the iron. An average sample of the bar showed that the carbon

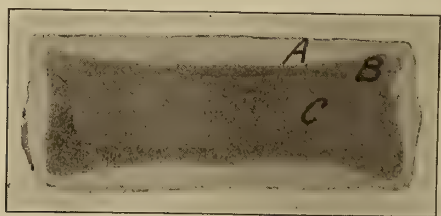


FIG. 1. CROSS SECTION OF GRAY-IRON BAR ANNEALED IN COPPER OXIDE PACKING

had been reduced from 2.70 to 0.60 per cent and that there was 21.4 per cent copper.

The test showed for this bar a strength of 68,200 lb. per sq. in. and an elongation of 1 per cent in 2 in. The electrical conductivity of the metal was not materially increased by the presence of the copper.

In other tests the test pieces were packed in black copper oxide and heated to about 900 deg. cent. The results were different and a far smaller penetration of copper was observed.

With gray iron quite different results from those for malleable iron were obtained. This is illustrated in Fig. 1, which shows a cross-section of one of the bars. Three distinct areas can be seen. The area *A* contains all of the copper. There is a thin layer of copper on the outside and next to this the copper is very finely divided and is in the form of droplike areas surrounded by a matrix of iron. This matrix has a peculiar structure and is more like steel than it is like gray iron. The line between *A* and *B*, Fig. 1, is shown in Fig. 2. The dark area is the portion containing the copper. The light portion in the same figure represents the structure of the section marked *B* in Fig. 1. The same structure is seen in

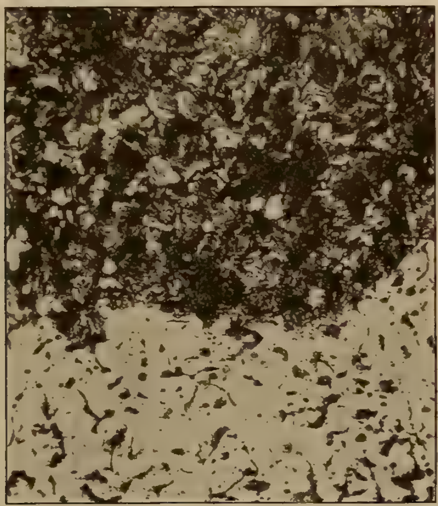


FIG. 2. DIVIDING LINE BETWEEN *A* AND *B*, FIG. 1

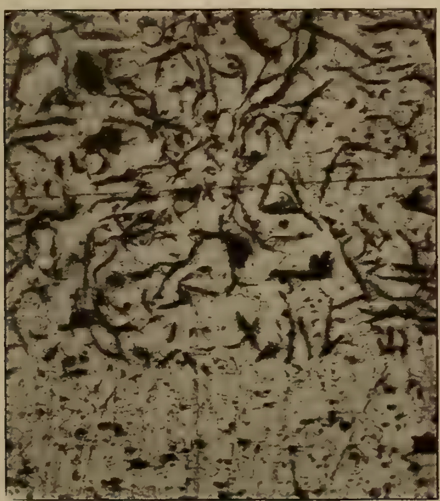


FIG. 3. STRUCTURE OF *B* AND *C*, FIG. 1

the upper section of Fig. 3, which is part of the dividing line between areas *B* and *C*. This structure is almost like the structure of malleable iron in its appearance under the microscope, but scattered through it can occasionally be seen flakes of graphite.

The center of the bar *C*, Fig. 1, has the structure of unchanged gray iron. This is shown in the lower section of Fig. 3.—*H. E. Diller, in The Foundry*, November 1, 1919, pp. 779-780.

TIN FUSIBLE BOILER PLUGS.

DATA of an examination, at the Bureau of Standards, of tin fusible boiler plugs for the Steamboat Inspection Service and of the tests made subsequently.

The experimental results show that there are six primary causes for the rejection of fusible plugs which may be roughly divided into two classes. Under the first class, rejections are included due to mechanical defects of casing material. The second class includes rejections due to lack of purity of the tin filling. The impurities in the latter case may be those either present in the original tin or those introduced during the manufacture of the plug.

The following conclusions have been reached as to the precautions to be taken in the manufacture of fusible plugs:

1. The pig tin should be at least 99.7 per cent pure, containing not more than 0.1 per cent lead, or 0.1 per cent zinc, which are the requirements of the Steamboat Inspection Service.

2. The casing should be of bronze, an alloy the major constituents of which are copper and tin. Small amounts of zinc and lead increase the ease of casting and machining and are not objectionable if not present in greater amounts than in the following compositions:

	I	II
Copper	88	87
Tin	10	7
Zinc	2	5
Lead	..	1

3. The pot or crucible for melting the tin should not be used for melting other metals, thus doing away with the liability of contaminating the good tin when these are not thoroughly cleansed.

4. Casings should be tinned on the inside with the same grade of tin used for filling, but the tin left over from this process should not be added to the filling to be used. Zinc-chloride flux may be used although hydrochloric acid if preferred, though no flux need be used during the filling process.

5. The casing should be preheated to not above 250 to 275 deg. cent. (482 to 527 deg. fahr.) and tin should be poured at a temperature not above 275 to 300 deg. cent. (527 to 572 deg. fahr.).—*J. Gurevich* and *J. S. Hromatko*, in *Bulletin of the American Institute of Mining and Metallurgical Engineers*, August, 1919, pp. 1351-1360.

ORIFICE MEASUREMENT OF WATER-PIPE DISCHARGE.

THE thin-plate orifice may be used with confidence for measuring the discharge of water through pipes. Like nearly all methods, it is subject to some limitations, although it helps to fill a growing need which has been partly filled by the pitometer and by the injection of chemicals. The pipe orifice is in effect a portable venturi meter, the disadvantage of the pipe orifice being the relatively large lost head caused by the obstruction of the orifice plate; however since the pipe orifice method is probabzly best adapted to temporary use the lost head caused by the orifice would be relatively small. Cases in which the pipe orifice should be of particular value have already been suggested in the introduction.

Although all the deductions and conclusions given in this summary apply to the measurement of water, attention should be called to the fact that the pipe orifice is adapted to measuring the discharge of air, gas, and steam through pipes.

The following points are important as a guide to the proper use of the pipe orifice method of measuring the discharge of water through a pipe:

1. The two sections of the pipe between which change in pressure head may be most reliably determined are the section at which normal flow is discontinued and the stream begins to converge as it approaches the orifice, and the section of greatest contraction of the jet after it leaves the orifice. Regardless of the size of pipe, for all sizes of orifice which it is feasible to use, the distance from the plane of the orifice to the section of beginning of convergence may be taken as eight-tenths the pipe diameter, and the distance of the section of greatest contraction as four-tenths the pipe diameter.

2. The drop in pressure head between these two sections is greater than that to be found for any other two sections near the orifice.

3. Having given the measured difference between the pressure head at the section of beginning of convergence and the pressure head at the section of greatest contraction the discharge may be determined through the use of one of two equations given in the original paper. (In one of these equations there is used a coefficient of discharge which is a variable quantity.) It decreases as the size of pipe increases; it decreases slightly as the drop in pressure head increases; it has a minimum value for orifices having a diameter of one-third that of the pipe and increases as the diameter of the orifice becomes greater or becomes less than one-third the diameter of the pipe.

4. The lost head caused by any given orifice in the pipe in terms of the velocity in the pipe may be determined by an equation given in the original paper, and is always less than the drop in pressure head between the section of beginning of convergence and the section of greatest contraction, but approaches it in value as the ratio of the diameter of the pipe to the diameter of the orifice (D/d) increases.

5. Due to the fluctuations of the liquid in the gage tubes the systematic error of reading the gage increases as the ratio of the diameter of the pipe to that of the orifice decreases, but when that ratio (D/d) is 2 or greater the error may under normal conditions of flow be reduced to a negligible quantity by a proper manipulation of apparatus. As (D/d) becomes less than 2 the accidental error of reading the gage increases very rapidly, and also small errors in the measurement of the diameter of the pipe or the diameter of the orifice are likely to be the constant sources of an error of increasing magnitude in the computed discharge. The indications are that, for favorable conditions of flow and with care in installing the apparatus and in observing, discharge may be determined generally within 2 per cent when the diameter of the orifice is not in excess of two-thirds that of the pipe, but this size of orifice seems to be about the maximum that can be used except for approximate determinations of discharge. When the magnitude of the lost head is not the controlling factor in the choice of size of orifice, best results are likely to be obtained if the diameter of the orifice is not greater than one-half that of the pipe.

6. For orifices having a diameter greater than one-half that of the pipe the use of two opposite pressure openings at each section is important because of the probability of the orifice being somewhat eccentric with the pipe, unless greater care is taken in placing the orifice than will usually be found practicable. Systematic errors of observing may be greatly reduced by proper throttling.

7. The coefficient of discharge for bevel-edged orifices is a much more variable quantity and is materially greater than the coefficiency of discharge for thin square-edged orifices. The use of the bevel-edged orifice seems not to be practicable, except for approximate measurements when the orifice diamter is greater than two-thirds of the pipe diameter.—*Raymond E. Davis and Harvey H. Jordan*, in *The University of Illinois Bulletin*, Dec. 2, 1919.

TURBINE-GEAR DRIVE FOR TORPEDO-BOAT DESTROYERS.

The design of propelling machinery for destroyers is an unusually difficult problem in view of the fact that a 1,200-ton destroyer requires propelling machinery of a capacity equal to that put into a 30,000-ton battleship and that this machinery must be operated by a force of 30 to 40 men in the small boat as against 200 in the large boat.

The relatively greater power required by the destroyer is due to its higher speed. The power required increasing approximately as the fourth power of the speed and the two-thirds power of the displacement. As the propeller speed can be increased with the ship speed, the speed of the propelling machinery can also be increased, in addition to which the type of machinery must be of the simplest form possible consistent with reliability and economy.

Increased rotative speed means decreased size and weight of driving machinery. The use of reduction gears allows the main turbines to have higher speeds, which, in its turn, leads to decreased steam consumption with the resultant decrease in weight of fuel necessary for a given cruising radius. Furthermore, with the high-speed geared turbines a relatively large number of rows of blades or stages can be used at slower speeds, at which the boat chiefly operates, which tends to give good efficiency at these speeds.

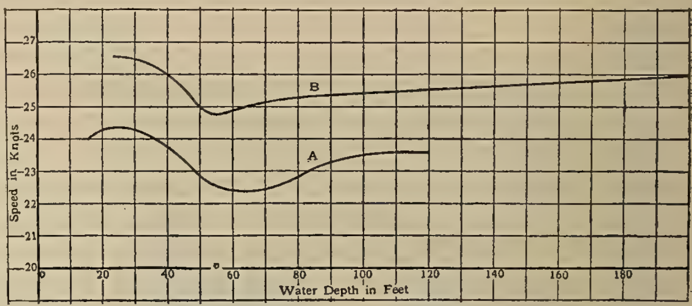


FIG. 4. SPEED CURVES OF DESTROYERS IN VARIOUS DEPTHS OF WATER AND CONSTANT INDICATED HORSE-POWER

The article gives brief information on the fuel economy of boats of the "Clemson" type compared with similar data of the U. S. battleship "Tennessee." It is of interest to note in this connection that in unofficial builders' trials on the "Clemson" at about 30 knots the machinery developed a shaft horsepower on slightly less than one pound of oil per hour, and that the boats reached a full speed ahead of 35 knots.

Interesting data are presented in reference to the influence of the depth of water in which a boat is moving on its speed. In general, the deeper the water up to at least one boat length, the faster the boat will go with the given propulsive power, but with long narrow boats of the torpedo or destroyer type there may be a shallow depth at which the boat speed will actually be higher than at any greater or lesser depth. This is shown in Fig. 4 made from trial data and has been confirmed in trials of the destroyers of the "Clemson" type.—*W. B. Flanders*, in *The Electric Journal*, November, 1919, pp. 474-476.

PRESENT LIMITS OF SPEED AND POWER OF SINGLE-SHAFT STEAM TURBINES AND TURBO-GENERATORS

The steam turbine is a comparative new comer in the field of prime movers and it was only about ten years ago that units of 5,000 to 6,000 kw. were considered in the light of highly hazardous experiments. Today units as large as 60,000 kw. are considered to be perfectly practicable and both operating engineers and manufacturers of central station equipment are interested to know whether there are any limits, mechanical or economic to the size of turbines.

The general feeling seems to be that the chief limitations are economic, in that extremely large units are still very costly per unit of power developed and involve greater risks in case of disablement. At a recent meeting of the American Institute of Electrical Engineers representatives of the largest manufacturers of turbo-electric equipment in this country presented three papers of sufficient general interest to make the following abstract:

The first paper by Eskil Berg starts by showing that the limit of a single unit turbo generator does not lie in the generator, but is confined to the steam turbine and that the limiting feature of the latter is the last wheel. The paper is based mainly on the work done by the General Electric Company.

Questions of design of the large turbines and of the conditions limiting the size are discussed.

Efficient action of the blades in large-sized turbines operat-

ing with the high vacuum can be accomplished only by using the bucket speed that bears a proper relation to the steam velocity, which means that to get the largest capacity not only long buckets must be used but they must be moved at a very high speed. On the other hand, to obtain good bucket action the buckets should not be more than about one-quarter as long as the pitch diameter of the wheel.

The use of a high steam speed in the last stage naturally implies that a relatively large proportion of the total steam energy must be utilized there and such concentration of work into a single stage has its disadvantages even if the best relations of velocities is maintained.

Since such a stage is doing a large amount of work, it is naturally less efficient than a stage of similar character doing less work.

In this way the last wheel of the turbine becomes one of the limiting features of the over-all dimensions. Energy and efficiency curves (Fig. 5) of the last stage are given which show that at the most efficient point, this stage absorbs 11.5 per cent of the total adiabetic available energy and that the wheel efficiency is 66.25 per cent. But this is for an output of 21,000 kw. and in the same turbine when the load increases to 36,000 kw. the energy in the last stage is 20.9 per cent of the total energy and the wheel efficiency goes down to 54.2 per cent.

The conclusion which the author comes to is that for a given speed there is one particular size of turbine which can be designed to be most economical as to steam consumption, weight, space and price per kilowatt. Even if a size smaller than this is required, it would, in many instances, pay for the central station to install a larger unit, even though it would have to run at reduced load for some time before the station load increased sufficiently to utilize its full capacity.

F. D. Newbury discusses the conditions determining the size of a turbine and conditions limiting it.

In the opinion of the writer, maximum output at any speed when reduced to the simplest terms is attained when slot space is provided for the maximum possible ampere turns (in either stator or totor) and core cross-section is provided for the maximum possible flux.

These conditions require the most effective rotor diameter and the maximum rotor and stator core lengths.

The most effective rotor diameter for a given speed is not necessarily the largest diameter and to obtain maximum output at a given speed the rotor proportions must be chosen properly to balance mechanical stresses, rotor ampere turns and flux.

The electrical factores in generator design are discussed by the writer who believes, among other things, that a fundamental difficulty in setting down definite limiting outputs is the difficulty in arbitrarily setting limiting stresses.

On the other hand, limit of length of the rotor and stator cores is determined mainly by such considerations as cooling air requirements, bearing proportions, by limits to weight imposed by transportation facilities and the ability to secure forgings of necessary diameter and weight.

To give an idea of the character of these limitations, it may be stated that, for example, transportation facilities may impose a limit to size in the case of 6- and 8-pole 60-cycle generators. From the special nature of their design and the special skill and equipment required for winding and assembling, rotors should be completed at the builder's factory and shipped as a unit. The weight of the complete rotor of a 4-pole 1,800 r.p.m. generator of 40,000-kva. capacity will be roughly 90,000 lb. This can be transported without difficulty, but the largest possible 1,200-r.p.m. rotor would weigh more than 200,000 lb. and would require rolling stock and trackage in some cases not now available.

Another general limitation to output of larger diameter rotors is that imposed by the forging facilities of the country. At the present time it is not possible to obtain forgings of suitable physical characteristics weighing more than 50 or 60 tons nor much larger than 50 in. This limits the rotor made from a single forging to an output of roughly 50,000 kva. at 1,500 r.p.m. By adopting the rotor construction involving 2 or 3-in. plates and up-set flanged shaft ends, the limiting diameter may be increased sufficiently for the largest 1,500 and 1,200-r.p.m. outputs shown in Fig. 6.

This figure shows in curve form limiting generator capacities at various speeds. At 1,500 r.p.m. and higher the capacity is determined by the rotor and is inversely proportional to the r.p.m. squared. At lower speeds the capacity is limited by the stator and falls somewhat below the correspond-

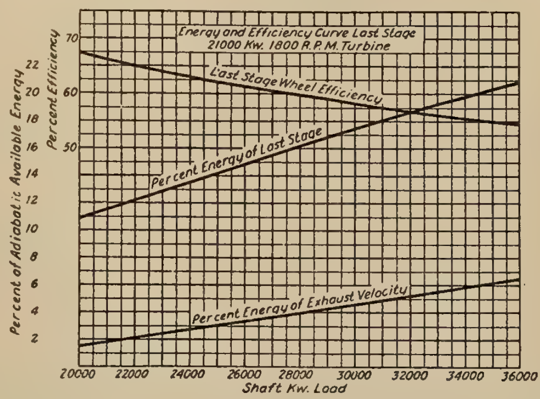


FIG. 5. ENERGY AND EFFICIENCY CURVES (LAST STAGE) OF A LARGE TURBINE

ing rotor limiting capacity, as indicated by the dotted expansion of the rotor curve. The curve is an indication of the present boundaries based on existing commercial materials and current stresses are bearing proportions. In fact, the capacities shown by it are somewhat in advance of accomplished results.

The writer claims that mechanical forces due to short circuit and damage caused by armature winding failures are no greater in the very large generators indicated by the above figure, than the present-day 20,000-and 30,000-kva. unit.

No opinion is expressed as to the wisdom of installing

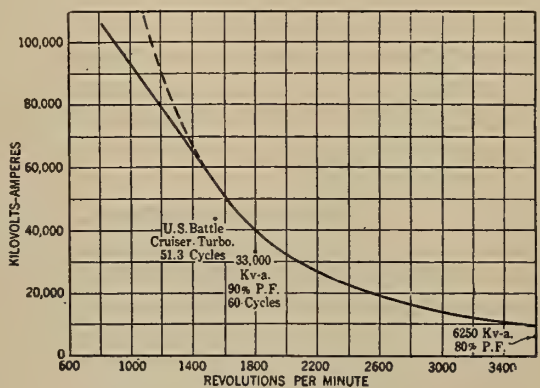


FIG. 6. LIMITING GENERATOR CAPACITIES AT VARIOUS SPEEDS

very large single-shaft units. If operating engineers desire units of 50,000 to 100,000 kva. there is no question but that such generators can be conservatively designed and constructed.

The paper by J. F. Johnson is restricted to a discussion of some of the factors which influence limits as applying particularly to turbines of the reactionary type. Here again the author expresses the opinion that with the employment of high vacuum the limit of power is determined largely by the area obtainable through the last stage, for the final expansion and passage of the steam prior to its entering the condenser.

The significance of this is shown by the fact that whereas a pound of steam when entering the first stage has a volume of less than 2½ cubic feet when passing through the last stage it has a volume of approximately 395 cubic feet if expanded to 28.5 in. vacuum, and 585 cubic feet is expanded to 29 in., the ratio in the latter case being 1 to 234.

Because of this, in any discussion of limits of power, it is necessary to assume conditions of pressure and superheat of the steam entering the turbine, the vacuum to which the steam is to be expanded in the blading and the efficiency of change of steam flow per unit of power.

The limiting factors are divided into three classes by the author. (1) Theoretical, including limiting steam velocities and effect on efficiency of velocity remaining in steam after leaving the last stage, and the area through the blades as affected by blade angle. (2) Physical, including methods of construction, materials, stresses, factor and safety against rupture, reliability factor, and limitations of transportation facilities; (3) Economical, including limits beyond which it may be physically possible but economically inadvisable to go, such as effect of size of structure or of character of materials employed on costs and time required to make inspection and repairs. The paper is largely based on the practice of The Westinghouse Company.

As regards theoretical limits with materials of infinite strength and rigidity it would have been possible to build units of infinite capacity, but for a given diameter and blade height the capacity is limited by chosen maximum values of steam speed through the blades, in order to keep the energy available in the steam discharged to the condenser within permissible limits.

Throughout the entire turbine, with the exception of the last few stages, steam speeds only about 25 per cent in excess of the corresponding blade speeds are employed in order to secure maximum efficiency. In the latter stages, however, the volumes become so great that steam speeds are increased sometimes approximately 100 per cent in excess of the blade speed, in order to effect a compromise between maximum theoretical efficiency and physical dimensions.

The question of blade angle is discussed next.

As regards the physical limits, the chief ones limiting turbine capacity are the physical characteristics of the material employed and the chosen limits to which these materials may be safely stressed.

Of course, the design of the rotor materially affects the stressed involved, but if the rotor design can be so modified as to keep the stresses within necessary limits, then the stresses at the base of the limits or in blade fastenings determine the maximum capacity obtainable with its given speed.

There exist two interesting relations between the stress at the base of blades, steam passage area through the blades, and rotative speed. For any given rotative speed and blade angle, the steam capacity or steam area through the blades is directly proportional to the stress at the base of the blades, regardless of the diameter and blade height selected. This stress can only be modified by unevenly varying the cross sectional area of the blades, such for example, as thickening the blade near the base. Also for any given stress the area through the blades will vary inversely as the square of the speed, *i. e.*, if at a speed of 1,800 r.p.m. a given stress and area are obtained, then at 900 r.p.m. the area will be increased four times if the stress is kept constant.

In other words, as the writer shows in the original article, the area and stress are each equal to a constant x the product of mean diameter and blade height and when the stress is constant this product varies inversely as the square of the revolutions per minute. The ratio of blade height to rotor diameter is therefore not a factor in determininng physical limit of capacity, but only in determining efficiency cost and, to some extent, reliability of the turbine.

Increased capacity without decrease of rotative speed or increase in stresses may be obtained by employing multiple low-pressure stages and a curve is given showing the limits of capacity of steam turbine with double-flow low-pressure stages.

In considering the economic limits of turbines of large capacity, consideration is given to the fact that as yet such units are not required in sufficient quantity to warrant equipping and operating shops for their exclusive manufacture, and that they must be produced largely by the same processes and equipment as are used for smaller sizes which are built in greater quantities.

As the sizes become larger, a greater proportion of special equipment and processes becomes necessary, resulting in increased rates of cost unless accompanied by very material increase in production of quantity.

Another factor tending to limit capacity of single units is the generating capacity loss resulting from suspension of service for inspection or repairs.—*Proceedings of the American Institute of Electrical Engineers*, Nov., 1919, pp. 1243-1253.

ITALIAN WATER TURBINES.

In the course of a tour through Italy and France, the author has seen under construction a rather unusual type of water turbine. It is to be used to produce power for the Italian electric state railways. The machine consists of two Pelton wheels of different diameters, employing varying heads of water, the water in question being drawn from two different sources of supply. Of the two wheels which are upon the same shaft, one is operated by a head of 2,000 feet and the

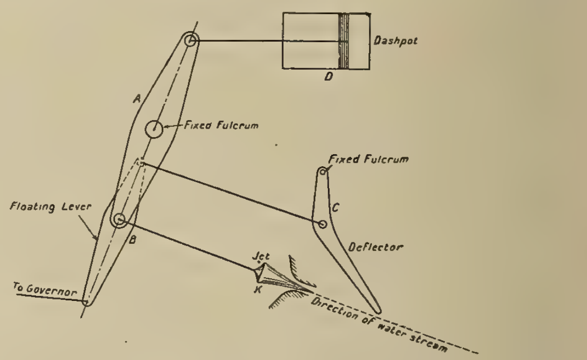


FIG. 7. RIVA SPEED-CONTROLLING ARRANGEMENT FOR PELTON WHEEL TURBINES

other of 670 feet. As a large variation of load occurs throughout the 24 hours, the plant is fitted with an automatic device by means of which a smaller wheel which is only used when the load rises to a certain point may be put to work. The diameters of the two wheels taken at the centers of the buckets are 6.4 ft. and 3.67 ft., respectively, and the speed 500 r.p.m. The larger diameter wheel develops 3,500 hp. with one jet and the smaller wheel 2,500 hp. with two jets.

An interesting feature of the Riva turbine of the Pelton type is the method of governing speed, or rather the control of the water jet. This is effected in two ways—first by deflection and next by throttling (Fig. 7). In it A is the lever working on a fixed fulcrum. To one end of this lever is attached a dashpot D; on the other end is fulcrumed the floating lever B. One end of this floating lever operates the deflection C and the other is connected with the governor. The fulcrum itself is connected with jet K.

Suppose the load to be suddenly removed from the turbine and raising commence. The governor immediately reacts on the floating lever B and the deflector comes into action on the water steam. Since resistance is offered in this operation to the turning of the lever B about its fulcrum, the fulcrum itself becomes a moving point about the fulcrum of the lever A and the jet K begins to close. The arrangement is really an application of the floating lever principle as used in various differential gears to this particular purpose.—*Norman Davey*, in *The Engineer*, Nov. 7, 1919, pp. 456-457.

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

LIGHT WAVE TELEPHONY.

An interesting series of experiments on the transmission of speech by light was described by A. O. Rankine in a recent communication to the Physical Society of London. The experiments showed that the method is practicable for considerable distances, while the fact that the apparatus is portable indicates that it may be of practical utility in certain cases. The theory of the process is given as follows, in the article:

The notable property of selenium of varying its electrical conductivity when exposed to illumination of various intensities has long been well known. It has led to various attempts being made during the last thirty or forty years to transmit speech over considerable distances by means of a beam of light which fluctuates in intensity in a suitable manner. Given such a beam of light the mode of reproduction is simple. A circuit is made consisting of a selenium cell exposed to the beam, a telephone receiver, and an electric battery. If the intensity of the beam does not vary, the electric current through the telephone receiver remains constant. But, if there have been impressed on the beam fluctuations of intensity corresponding in amplitude and frequency to the vibrations of speech or other sounds, the selenium, if it is capable of adjusting its conductivity with sufficient rapidity, will control the current in the telephone in such a way as to reproduce the original sounds.

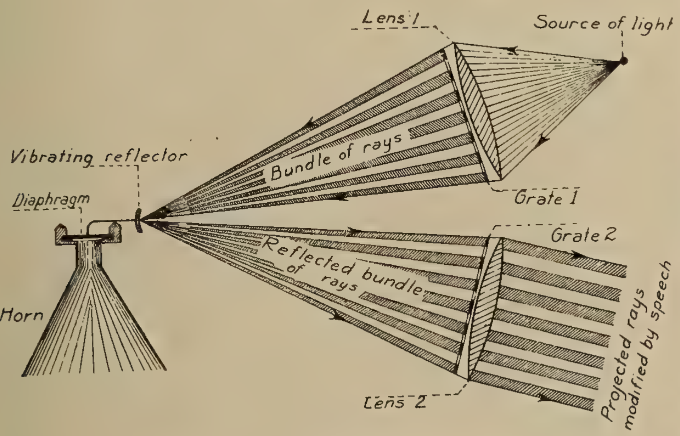


FIG. 1. THE TRANSMITTER

The methods of telephoning with light hitherto used may be divided into two classes. In the first, the aim is to cause the speech to control the illuminating power of the source itself. For example, if the current in an electric arc can be controlled effectively by microphonic action, the light issuing from the arc may be expected to have the character desired. The second general method is to effect the control of the beam by causing the speech to interrupt the light, with the proper periodicity and amplitude, *after* it has left the source, the actual illuminating power of which remains constant.

Of these two modes, there is little doubt that the second is the more effective and useful. In the first place, it permits the use of the sun's light as the source, whereas, in the other method, artificial sources only can be used. This, it will be seen later, is of considerable importance. It is desirable, also, that the changes of intensity brought about by the speech should be made as great as possible. In the case of an arc controlled microphonically, however, even if the current oscillates from zero to its maximum value—which is unlikely the variations of light intensity must still be comparatively small at the frequencies in question. If we take the average frequency of speech sounds as about 500 per second, it means that the brightness of the arc must alternate between maximum and minimum every 1/500 second, during which time the actual variations of its temperature, and, therefore, of its brightness must be small. Speech would thus impose no more than a ripple of small amplitude upon the already powerful beam of light emitted from the arc. On the other hand, by controlling the beam after it has left a constant source, it is possible, particularly by the method about to be described, to guarantee that the fluctuation of the beam traverses the widest possible range.

Both methods have been used with a certain amount of success. In a patent specification of 1889, Graham Bell describes two devices falling under the latter class. In the first, the proposal is to allow the beam of light to pass in succession through two grids consisting of equal parallel strips alternately opaque and transparent. One of these is fixed in position, and the other is moved bodily, in a direction perpendicular to the strips, by the operation of a diaphragm to which it is rigidly attached, and on which speech sounds fall. The movements of the diaphragm may be expected, therefore, to control the obstruction to the beam of light in such a way that the intensity of the emergent beam varies in accordance with the speech sounds. The practical objection to this device is that, ordinarily, the movements of the diaphragm are so small that it would be most difficult, if not impossible, to make grids at once so light, so rigid and so fine as to fulfil the necessary conditions. Graham Bell does not, in fact, claim that this method has been actually used. His second device is much more sound from a practical point of view. It relies upon the fact that a vibrating diaphragm is continually altering its curvature; consequently, if polished, and interposed in a steady beam of light, it will give rise to a reflected beam which is of variable divergence. Although the total amount of light reflected is actually unaltered, the fraction of it incident at a distance upon a receiver, not large enough to include the whole beam, will have a value controlled by the vibrations of the diaphragm. The objection in this case is that the diaphragm must be large in order to deal with a large quantity of light; for, if it is placed at a point where the beam has been concentrated to a focus, the effect of its changes of curvature upon the divergence of the beam is negligible. Further, from an acoustical point of view, it would be necessary for the diaphragm to be thin, and it would, therefore, not be suitable for adaptation as a mirror of good optical properties.

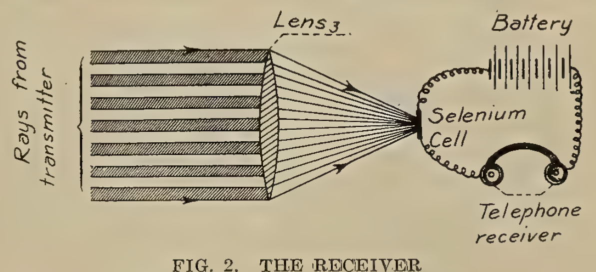


FIG. 2. THE RECEIVER

Mr. Rankine overcomes the difficulty caused by the weight of the grid, mentioned previously, by ingeniously substituting the *image* of a grid for the grid itself. To accomplish this an

optical system is arranged in which the light from the source is concentrated by a lens upon a small oscillating concave mirror, so arranged that, when in its position of equilibrium, it reflects the beam to a second lens by which it is again brought to a focus. A grid is placed between each lens and the mirror, with the result that a real image of the grid between the light source and the mirror is formed in the plane of the second grid.

If oscillations corresponding to human speech are now imparted to the mirror the image of the first grid, oscillating on the second grid, will give corresponding variations to the intensity of the emergent beam of light. A selenium cell, placed at the focus of this beam and connected to a telephone receiver and battery, will reproduce the sounds corresponding to the fluctuations of the light.

Several forms of apparatus are described. The transmitter may be constructed of a phonograph recorder, by attaching the mirror rigidly to the lever which ordinarily carries the needle; or a telephone receiver of the reed type, actuated by the variable current in a microphone, may be used instead. In another type of apparatus one grid is eliminated and the image of the single grid is superimposed on the grid itself, an arrangement which, in the author's opinion, will ultimately prove more efficient than that previously described.

Any source of light may be used, and the author used incandescent and arc lamps and sunlight successfully. The results obtained were encouraging. Conversation in both directions was carried on between stations 1½ miles apart, using a carbon arc for light, while the faintest whisper could be heard at this distance when sunlight was used. Using sunlight, Mr. Rankine estimates the range of the present apparatus to be approximately eight miles, but believes that this may be greatly extended by using amplifiers to magnify the currents in the receiving circuit.

AUSTRIAN ELECTRICAL INDUSTRIES DURING THE WAR.

A RECENTLY received issue of the Elektrotechnische Zeitschrift (v. 40, p. 322, 3 July, 1919) contains an account, by Emil Honigmann, of the Austrian electrical industry during the war. Little has hitherto appeared on this subject, as distinguished from the industry in Germany.

The war began at a time when economic and political conditions were reacting unfavorably on the industry and the first effect of hostilities was to paralyze it. The calling of the personnel to the colors, the disappearance of capital and the moratorium created an unprecedented situation and a dread of any movement. This situation lasted but a short time; demands for railway material and electrical machinery soon came from the army and soon afterwards the factories were arranged for munition manufacture.

Electrical factories turned especially to the manufacture of munitions, finishing shells, etc. There was also soon a large demand for shop equipment, dynamos, motors and apparatus of all kinds, and for wire and cables, telephones, telegraph instruments, and all the many varied electrical devices used by the engineering departments of the army and navy.

Other electrical undertakings were abandoned and every energy bent to meet military needs. Early in 1915, every shop was devoted to war manufactures and every lathe was busy. Soon the difficulties began to appear. Raw and intermediate materials began to be scarce, the best workmen were at the front and satisfactory substitutes were not easy to find. Electric power stations were busy as the shortage of petroleum increased the demand on them and more power was used.

During the summer of 1915 the copper shortage began to be felt and aluminum came into use. Substitutes cannot be introduced into manufacturing, however, as readily as into foods; their use requires changes in design, construction and operation. The difficulties, however, were gradually overcome. At the same time the cost of labor and material rose rapidly. Electrolytic copper rose over 220 per cent. between January, 1914, and October, 1915, sheet brass 200 per cent., sheet zinc 77 per cent. and tin over 200 per cent. Wages increased from 25 to 50 per cent. Manufacturing costs increased rapidly from other causes as well.

During 1916 and 1917 the industry followed the same path. New plants were built, in spite of soaring costs and the ever increasing shortage of materials. Careful research for substitute materials was undertaken. Every effort was made to bolster up financially weak concerns, prices were increased, and trade organizations formed.

In 1917 the food problem became acute and the factories were obliged to take up the rationing of their workers. After the invasion of Italy new supplies of material also became available and conditions were easier, but the peak was reached at the beginning of 1918. The long duration of the war, with its attendant breaking of morale and finance began to have its effect. Prices still increased, but no longer as rapidly as costs, and careful manufacturers reduced dividends and commenced a policy of economy.

In October, 1918, the armistice produced the catastrophe and the empire fell to pieces, carrying with it the industries of the country. Since that time the industry has stood still, with the outlook far from favorable, so far as the immediate future is concerned.

One technical effect of the shortage of material was the modernization of many old plants. A number of old direct-current installations were replaced by alternating-current distributing systems, to recover the greater amount of copper used in them. A considerable amount of lead was also recovered from the storage batteries with which many were equipped. In many cases the recovered metal practically paid the expense of the change.

EFFECT OF LIGHT ON THE EYE

THERE has long been an impression that yellow light is more agreeable to the eye than that containing chiefly the green and blue rays, and it is generally believed, for example, by many medical and technical men that the kerosene flame produces a more "restful" light than other illuminants, especially than incandescent solids. This supposition has been submitted to careful tests by C. E. Ferree and G. Rand, and the results have appeared in the Transactions of the Illuminating Engineering Society (v. 13, p. 50, and v. 14, p. 108).

The experiments have compared the kerosene flame with the light from the carbon incandescent lamp, the Mazda lamp, types B, C and C2, and with Welsbach mantles containing various amounts of ceria, and therefore varying in yellowness. The standard of comparison is the efficiency of the eye as determined by the ratio of time during which steadily observed type appears clear or blurred.

The results obtained from numerous careful, prolonged experiments indicate that there is some justification for this impression, as they indicate that the efficiency of the eye diminishes more rapidly with light from the metal filament than with that from kerosene, and decreasing yellowness in Welsbach mantles also diminishes this efficiency of the eye. The authors, however, are not yet prepared to state positively that yellow light is better than white, but merely that yellow is better than green.

BREAKAGE IN HIGH-TENSION INSULATORS.

THE *Electrotechnische Zeitschrift* has recently published (Nos. 16, 17, 18 and 24, 1919) an extensive report on the causes of failure in insulators for overhead transmission lines, by E. O. Meyer. The following abstract of the original communication, taken from the *Electrician*, 24 October, 1919, gives the main results obtained in the inquiry.

A transmission line was constructed in Kreuzwald between 1911 and 1914, consisting of 320 km. of line, carrying current at 65,000 volts. At first there were breakages, due largely to

accidental causes, mostly connected with transport and construction; but in the process of time, mostly in 1915 and 1916, the breakages increased considerably in number and caused numerous stoppages. At 65,000 volts, in bright dry weather, there is a marked hissing sound from an insulator; if it is defective, it gives either no sound at all, or a very strong extraordinary hiss. In either of these cases it ought to be changed without delay, to anticipate a possible breakdown. Records showed that in this case the cracks were exclusively on the upper part of the insulator, which consisted of three portions cemented together. There were always two characteristic cracks: the one goes radially in a plane through the axis of the insulator, tending to split it into symmetrical halves; the other goes somewhat in the form of a ring around the top.

Mechanical causes did not seem likely to produce the result. The binding wire might be loose and tend to hammer the insulator in rough weather; but this was not found to be the case, as the binding was nearly always tight on the cracked insulators; neither could the expansion of the pin cause the breakages, as it would tend to break the lower parts as well.

Electrical effects were examined. Naturally, the uppermost phase is most exposed to direct and indirect atmospheric effects. But records on the line in question showed that the disturbances were not at all confined to the uppermost phase, but were nearly equally distributed, though the phase affected by lightning was more generally the uppermost phase. It was thought possible that the insulators were not big enough for the pressure; but it so happened that, owing to accidental causes, certain long lengths of the line were worked for some months at 10,000 instead of 65,000, and the breakages continued as before.

It was suggested that as the cement dries it alters its electric conductivity, and consequently affects the distribution of the lines of force; but the author regards this suggestion as improbable. Air bubbles in the cement might give rise to glow discharges, and to very slight internal heating; but this would scarcely be likely to attack or burst porcelain. Peasley, in America, put forward the suggestion that an insulator might be injured if it were subjected to a high-frequency surge as well as to a voltage of low periodicity; but this is not proved.

The shape of the insulator is next examined, as being possibly a contributory cause. The author examined this matter in some detail, he finds no clue to the solution of the problem in hand. He also collected together in tabular form such figures as are available with regard to the technical properties of porcelain itself; but there is no definite agreement as to these figures, and some makers felt themselves not to be in a position to make any positive statement on the point.

It was next suggested that temperature effects might explain something. The author quotes a series of tests which he carried out on porcelain balls; these certainly cracked if the change of temperature was very marked, much more so than is likely to occur in practice; but generally speaking, the cracks were across a meridian, and this is not of the characteristic type noticed in insulators. There was no distinct proof that anything could be due to this cause; but it is possible that the temperature may affect the cement, and so injure the procelain indirectly. Records show that on the 65,000-volt line, to which this investigation had special reference, most of the breakages take place in summer, and not specially in thunderstorms, but in bright cloudless weather. Temperature, therefore, undoubtedly has some effect.

Thus, finally, there remains only the question of the cement. Portland cement is now mostly used, and Dr. Riepert says that cement expands slightly on setting, but the expansion and possible subsequent contraction depend on the conditions—*e.g.*, whether it sets under water or in the air. This is common to all cements, but a poor cement also "drives"—*i.e.*, it is liable to crack and destroy anything within which it is enclosed. This "driving" begins sooner if it hardens under water than if it sets in the air. Cement can be tested by making a small block and allowing it to set for one day in the air, and then for a month under water. It ought then to show no cracks on the top, though some "driving" cements will show cracks in three days. There are sometimes curvatures and cracks on the edges of the block. The cracks run mostly in the direction of the middle of the block and gape most at the edge; often they are connected with a network of fine cracks. These cracks must not be confused with those which are liable to form while it sets in air as it dries; the latter form irregular curved lines over the surface. The blocks, while setting ought to be protected from draughts and sunshine. Cements with more than 5 per cent of magnesia, if burnt till they sinter, do not show marked signs of "driving" till several years have expired. Cement must be kept moist during the first stage of hardening, and is liable to crack if the block is put into water too soon. The "driving" of the cement seems, in the view of many competent persons, to be the main cause of the characteristic cracking. Since the magnesia content is the determining factor in the "driving effect," several cements were chemically tested which were taken from insulators that had cracked, some of them after having been in use seven years. The results of these analyses are given. In no case was there 5 per cent. of magnesia, the figures actually being 1.04, 2.4, 2.79, 0, and 0.92 in the five cases respectively. The "driving" and expansion of the cement cannot be entirely avoided, and there are other points in connection with the cementing process which require careful attention. The cementing mixture must not be too dry, and the moisture must be evenly spread throughout the mass. In some cases the cemented joint has shown on fracture a very uneven distribution of the cement. Sometimes there is too much on the one side or on the top. If there is a thick layer of cement on the one side and a thin one on the other, the crack will take place on the thick side. It is, therefore, necessary to see that the design only allows for a thin layer of cement, which must be evenly distributed. According to the experts, cement takes two years to set fully, and this possibly helps to explain why the fractures only take place after several years. After it has set, cement becomes a rigid substance, which is almost entirely a non-conductor of heat.

Improvements in manufacture are, therefore, an urgent necessity. The cause of cracking lies in the cementing process by which the parts are joined together. The specification of the latest type for 65,000-volt insulators prescribes a maximum thickness for the cement layer of 2 mm. at the top and 3 mm. at the sides of the cylindrical surface. On 45,000-volt insulators the manufacturing process has become so exact that the thickness varies between 1.5 mm. and 2.5 mm. The parts to be cemented together must fit exactly in point of size, and must be sorted for this purpose. The choice of the cement, the character of any admixtures, the preparation of the cement paste, its moisture while setting, and the keeping of the insulators a sufficient time in store without disturbance—all these things need attention. A coat of lacquer on the surfaces to be cemented has been tried, but this is not likely to effect much, as shellac oxidises and becomes hard and inelastic. A sheet of lead foil has been tried, also cork insets and metallic plates; but these are all useless. Lately a coat of graphite paint 0.1 mm. to 0.3 mm. thick has been tried, and also a thin copper ring; but this idea seems likely to fail, inasmuch as this constitutes no sufficiently rigid connection. Experimentally it has been proved that a slight movement is possible with these semi-elastic joints; this is likely to prove fatal in everyday work. The copper foil is so delicate that it is often injured in the cementing process. Drawings are given of two modern types of high-tension insulator, with dimensions and test pressures; in these cases there is a kind of hemispherical joint between the various parts. No kind of elastic joint is used. If improvements on these lines can be made, the pin insulator will be preferable to the suspension type, which costs in all at least three times as much, apart altogether from the fact that the poles must be 5 ft. or 6 ft. longer.

Progress in Mining and Metallurgy

A Summary of Important Articles in Current Periodicals

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

PROPERTIES OF STANDARD OR STERLING SILVER.

STANDARD or sterling silver, which contains 92.5 per cent of silver and is the only silver alloy of industrial importance, derives its name from the fact that, from very early times, it has been the legal standard alloy for all British silver coinage and, so-called, silver plate. When the alloy is cast, there is a tendency for the silver to become concentrated in the middle of the ingot, but when proper precautions are taken the differences in composition in different parts of the ingot are not sufficient to interfere seirously with the application of the alloy to minting and to industrial purposes. They found the temperature of the metal in the crucible, when ready for casting, to be about 1,200° C., and that of the stream during pouring to be about 1,113° C. The best temperature for annealing, in works practice, had been found to be 670° C. for all-around work. The time varied according to the thickness of the sheet but, generally, annealing was complete in from 20 to 30 minutes. The maximum Brinell hardness of standard silver was about 183. The maximum tensile strength varied from 11 tons to 14 tons per square inch according to the method of casting.—*W. E. A. Smith* and *E. H. Turner*, in *The Engineer* (London), Oct. 10, 1919.

DRILLING AND PRODUCTION TECHNIQUE IN THE BAKU OIL FIELDS.

BY ARTHUR KNAPP.

No OIL territory in the world has been so rich in large producing wells, in a comparatively small area, as the Baku field. Particularly is this true of the Bibi Eibat field, which formerly produced millions of "poods" of gusher, or as it is called in Russia, "fountain" oil. The Bibi Eibat and Balachany fields have been exhausted of gas and ruined by water, but the Surachany and Benegadi fields are still fountain territories and many outlying districts that have only been prospected produce rich fountains.

The method of controlling "fountains," or gushers, is the result of growth, along with the Russian system of drilling, where large diameters and riveted casing have been in vogue. The screw casing is seldom used except to exclude water. Formerly the method of finishing wells and the condition of the casing at the top of the well would not permit the use of gates, manifolds, and connections, as in standard methods elsewhere. The life of the flowing wells is very short, particularly those 10 in. (25 cm.) or more in diameter, which produce large quantities of sand and often flow for but a few days and are then a complete loss. More than 1,000,000 poods in 24 hr. have been claimed in several instances, but in no case was the flow for more than few days.

The oil sands of this district are free uncemented sands and vary in thickness from paper thin to a maximum of 10 ft. (3 m.). The sands are interlaid with strata of soft clay. In spite of this, the practice has been to drill into such sands and produce from the open hole without screen or liners. Sometimes the casing is set below the oil sand, but in this case holes from 2½ to 3 in. in diameter are drilled opposite the oil sand, which would not have the effect of a screen.

The Russian method of drilling makes use of steel poles to actuate the tools but differs from the Canadian system, which uses poles of wood or iron, in that a "free-fall" is used above the tools instead of the tools dropping with the rods. This free-fall picks up the tools at the bottom of the stroke and releases them at the top of the stroke, allowing them to fall free to the bottom of the hole. Thus the fall is limited to the length of the stroke of the walking beam and differs from the American cable tool system where the fall, due to the elasticity of the drilling cable, may be several times the stroke of the beam.

The Russian drilling machine is a slow ponderous machine, very heavy and very hard to handle, transport, and install. It cannot be said in reality that this machine drills, but eventually it manages to worry a hole into the ground.

The general character of the Russian method accounts for most of the slow progress, together with poor tools, material, and labor. Wells are usually drilled by contractors who are paid per linear foot on a sliding scale, depending on the depth. They are paid by the day while fishing and are not liable for casing lost.

FORGEABILITY OF IRON-NICKEL ALLOYS.

BY T. D. YENSEN.

IN the investigation of the magnetic properties of iron-nickel alloys, it was found necessary, in order to make the alloys forgeable, or malleable, to add small quantities of some other element. Iron-nickel alloys have been known for nearly a century, but have been made in commercial quantities only since 1885. The chief difficulty in their development was that the "pure" alloys did not forge readily. The addition of small amounts of manganese, however, made the alloys forgeable. The present paper shows to what extent manganese is needed for various nickel contents and also what is the effect of other alloying elements on the forgeability.

The forgeability is given for the four conditions: Cold, black heat, dull red, and bright red. Cold means a temperature of 20° to 100° C.; black means any temperature below the appearance of redness, that is below 600°; dull means 600° to 900°; and bright, temperatures above 900°.

Up to 7 or 8 per cent nickel, the forgeability is fairly good at a dull red heat. The effect of silicon on the forgeability is very slight, if it has any. Aluminum, carbon, and magnesium have no beneficial effect upon the forgeability. Manganese, as was anticipated, makes the alloys forgeable. Of all the different elements tried, titanium has the most beneficial effect on the forgeability.

REVERBERATORY FURNACE FOR TREATING CONVERTER SLAG AT ANACONDA.

BY FREDERICK LAIST AND H. J. MAGUIRE.

THE ore from the Butte mines of the Anaconda Company contains considerably less iron than is needed for the fluxing of the silica. As the losses in the concentrator were high, compared with the losses in the blast furnaces, it was found, by calculation, more profitable to send ores containing more than a given percentage of copper to the blast furnaces in spite of the higher costs of treatment.

With the introduction of the flotation process, it was found possible to maintain an average recovery, as concentrates, of 96 per cent. The cost of reverberatory smelting was materially decreased by the use of pulverized coal. These two changes in practice made the blast furnaces unable to compete with the reverberatory furnaces on a cost basis.

The amount of basic fluxing materials required for the smelting operations became small and the converter slag lost its former value as a blast-furnace flux. For this reason, a less expensive method of recovering the copper, silver, and gold contained in it than smelting in blast furnaces had to be found. It was not feasible to pour the slag into the regular reverberatory furnaces.

It seemed that the successful traetment of the converter slag would require the reduction of Fe_3O_4 contained therein to FeO. Silica would have to be furnished to combine with the FeO so as to produce a slag containing not less than 30 per cent silica. At the same time, iron sulfide would have to be furnished to combine with the particles of metallic copper and white metal and carry them into a comparatively low-grade matter. All of these reactions, it was thought, could be brought about by the addition of unroasted or partly roasted fine concentrates and fine siliceous ore. The experiments were carried out under the supervision of F. F. Frick, research engineer for the Anaconda Co., and gave reasonably satisfactory results.

The average cost for treating converter slag during the year 1918, after segregating the cost of all other material, and assuming this other material to have pursued its regular course through the smelter, was $0.6126 per ton. The cost per ton for the second six months of 1918 was $0.4648.

PETROLEUM RESOURCES OF GREAT BRITAIN.

By A. C. VEATCH

THE present work in Great Britain had its inception in 1914, when the outbreak of the war enabled the writer and his associates to carry out a long-deferred desire to see just what the numerous indications of petroleum in Great Britain really meant. Thanks to the great mass of fundamental geological information which the Geological Survey of Great Britain had collected and published, and particularly to the detail work carried out in certain of the coal fields, it was possible in a short time to present to Lord Cowdray the conclusion that the petroleum possibilities of the Midlands of England were of a most amazing and striking character. With the increase of the submarine menace, he offered to place the services of his firm and his petroleum staff at the disposal of the nation, free of cost, for carrying this work forward as a war measure. This was a gift made to the nation without any commitment of any kind on the part of the British Government to Lord Cowdray.

The midlands of England contain large areas of important oil lands, which, however, will not become of commercial importance for at least five years, because the ownership of the oil has become a political issue. In the center of England the Mountain limestone (Mississippian) is exposed along the axis of the Pennine fold. Like the similar carboniferous limestones in Kentucky and Missouri, it is cut by spar and lead veins but, unlike those, it contains numerous important seepages of petroleum.

The discovery well is located on a faulted dome at Hardstoft, Derbyshire, where none of the coal mines had found oil in the fault planes. It started in the coal measures, found wax in drilling through a fault, a commercial supply of gas in the Millstone grits, which was muddied off, and oil in the top of the limestone at a depth of 3,078 ft. (938 m.). This well has been flowing at the rate of 12 bbl. per day since June of this year, and is estimated to have a pumping capacity in excess of 50 bbl.

Two wells located on domes south of Hardstoft, both started in the coal measures, penetrated the Millstone grits without finding gas in any considerable quantities, showed a little oil in the top of the limestone, and are now drilling in the limestone, where they have encountered a little gas. The two wells that are being drilled in Scotland are in an entirely different category. They are merely "wildcat" wells, with a moderate chance of being successful.

The oil from the Hardstoft well has the following characteristics: Specific gravity, 0.823; sulphur, 0.26 per cent; gasoline, 7.5 per cent; kerosene, 39.0 per cent; wax, 6.0 per cent; gas oil, 20.0 per cent; lubricating oil, 30.0 per cent. The oil is particularly rich in very high-grade lubricants.

CHEMICAL WARFARE.

By LIEUT. COL. AMOS A. FRIER.

CHEMICAL warfare is a complete science in itself. No other invention, since that of gunpowder, has made so great a change in warfare as gas. The air service is the only service that approaches it in the completeness of the change of methods of fighting. Today there are only four really distinct arms of the service; viz., the infantry, the artillery, aviation, and chemical warfare. All other forms of warfare are a combination of these.

No officer, however well trained in other duties under the War Department, can handle gas until especially trained in its use. It is the most universal of weapons and, as it drifts with the air, becomes the most difficult of all methods of warfare to avoid. No form of precaution heretofore used on land or sea is effective against it.

Considering its power, gas has no equal. Gas, used properly, will make the wearing of the mask a continuous affair for all troops within 2 to 5 miles of the front line, and in certain places, for many miles beyond. The reduction in physical vigor and, therefore the efficiency of an army forced at all times to wear masks, would amount to at least 25 per cent which is equivalent to disabling a quarter of a million men out of an army of a million. Gas, being heavier than air and yet carried with the air, with which it slowly mixes, rolls into depressions and dugouts and hangs among trees and rocks long after it has dissipated in the open. With it the sniper can be driven from his lair and countless American lives saved. Can any man afford, in the face of these facts, to say that America should give up gas?

If the United States must clean up Mexico or is forced to put down uprisings in the Philippines, in San Domingo, or any other place among peoples not thoroughly prepared with masks, the work can be done by using gas at a less expense and with far less loss of American lives than by any of all methods of warfare put together.

A FOREIGN OIL SUPPLY FOR THE UNITED STATES.

By GEORGE OTIS SMITH.

TWELVE years ago the Director of the United States Geological Survey addressed to the Secretary of the Interior a letter calling attention to the government's need for liquid fuel for naval use and pointing out that the rate of increase in demand was more rapid than the increase in production. This letter, in a way, inaugurated the policy of public oil-land withdrawals, which was well founded in its primary purpose of protecting the oil industry and highly desirable in its immediate effect of checking the over-development of that day in California. Unfortunately, however, through delays in legislation, this policy may be regarded now as having outlived both its extent and its usefulness. In 1908, the country's production of oil was 178,500,000 bbl., and there was a surplus above consumption of more than 20,000,000 bbl. available to go into storage. In 1918, the oil wells of the United States yielded 356,000,000 bbl., nearly twice the yield of 1908, but to meet the demands of the increased consumption more than 24,000,000 bbl., had to be drawn from storage.

Nor is this all of the brief comparison. In 1918, our excess of imports over exports of crude petroleum was nearly 33,000,000 bbl., whereas, in 1908, we exported 3,500,000 bbl., which was net, as we had begun to import Mexican oil. In this period, the annual fuel-oil consumption of the railroads alone has increased from 16,871,000 to 36,714,000 bbl., the annual gasoline production from 540,000,000 gal. to 3,500,000,000 gal.

This record may be taken not only as justifying the earlier appeal for Federal action, but as warranting deliberate attention to the oil problem of today.

The position of the United States, in regard to oil, can best be characterized as precarious. Using more than one-third of a billion barrels a year, we are drawing not only from the underground pools but also from storage, and both of these supplies are limited. In 1918 the contribution direct from our wells was 356,000,000 bbl., or more than one-twentieth of the amount estimated by the Survey geologists as the content of our underground reserve; we also drew from storage 24,000,000 bbl., or nearly one-fifth of what remains above ground. In a single decade, then, the consumption of fue loil by railroads has more than doubled; the consumption of gasoline has increased sevenfold. With the rapidly mounting cost of coal, the competitive field of fuel oil for steam use is expanding. We may lessen the increase in coal or oil consumption for generating power by harnessing the water powers of the country; but prime movers whether driven by steam or water, require lubrication.

A most serious aspect of our oil problem presents itself when we consider the entry of the United States as a real factor in the shipping of the world. Any nation that aspires to a large part in the world's commerce imposes upon itself an oil problem; for the future freedom of both the sea and the air will be defined in terms of oil supply.

A country-wide thrift campaign for saving this essential resource needs to be waged. Man power and oil ought to be conserved all along the line of production and consumption by better methods in the discovery, drilling, recovery, transportation, refining, and use of petroleum and its products.

The estimate by the United States Geological Survey of the oil remaining in the ground is, of necessity, subject to criticism as speculative, yet the excesses of unexpected yield in one region will largely be balanced by deficiencies in another. If happily the estimate of reserve proves too low, this unpredicted abundance would surely raise the consumption rate. On the whole it is fair to consider the official estimate of 6,500,000,000 bbl. as conservative and 8,000,000,000 as an improbable maximum. The difference between these two estimates of reserves represents only four years' supply, even at the present rate of consumption.

Two methods of handling the problem of a future oil supply suggest themselves; either reserve the domestic oil fields for American development and thus prevent foreign acquisition of what is needed at home; or, encourage our capital to enter foreign fields to assist in their development, thus insuring an additional supply of oil for our needs. The one method harks back to the "Chinese wall" period, the other expresses the "open door" policy. At present the United States Government follows neither method; the British Government has adopted both.

The British Admiralty led the way in its appreciation of the advantages of fuel oil, and the British Government has led the way in assuring to its nationals control of oil resources wherever found on British territory. Advantages that American capital may once have held in Trinidad and elsewhere in the British Empire are not now enjoyed and British enterprise is narrowing the field of opportunity in Mexico, South America, Mesopotamia and Africa.

RELATIONSHIP OF PHYSICAL AND CHEMICAL PROPERTIES OF COPPER.

By Frank L. Antisell.

Certain physical and chemical properties of copper are so intimately related that a change in variation of the physical properties indicates a certain chemical change. The standard specifications of copper of the American Society for Testing Materials are based upon physical characteristics with one exception, namely, the copper contents. Certain phenomena of the surface indicate the adaptability of the metal for forging or rolling. The writer believes that it is much simpler to produce shapes that are metallurgically correct than those that are mechanically satisfactory.

The appearance of the surface of the copper when cooled is considered as to its "pitch," or the general contour of the surface, and the "set," or the detail appearance of the surface of the shape. The set of the copper is, in a very large measure, directly related to the pitch; and so intimately are these characteristics connected that they are often used as synonymous terms by the refiner when he is speaking of well-refined copper. Oxygen is often spoken of as a medicine for copper, it being used to regulate the pitch.

The general physical properties of copper change in a marked manner with the increase of sulphur. An increase in the sulphur contents affects the number of bends in a very much greater ratio than does oxygen.

Reasons for rejecting refined copper on physical examination are: Low pitch; overpoling; cold sets; spewing; shot; fish (slivers of foreign copper, as the fins from the pouring ladle, etc.); holes of several characters, as water holes, shake holes, shrink holes, gas holes, spew holes, general porosity; foreign substances, such as charcoal, bone ash, dirt, etc.; splashes; fins; cracks; large set marks; water bursts; ridges on surface; shapes cast in rough molds; wrong dimensions; and collective defects.

GEOLOGIC DISTILLATION OF PETROLEUM.

By Bailey Willis.

In 1882, Peckham put forward a provisional hypothesis to account for the distillation of petroleum. He did not formally state the hypthesis, but in a discussion of facts drawn from many fields he made it clear that he regarded petroleum, and especially the petroleum of the Pennsylvania fields, as a "fractional distillate produced under high pressure and consequently at a comparatively high temperature."

The object of this paper is to test Peckham's hypothesis and the contributions to it made by White and Johnson by considering the geologic activities of the Appalachian province in the light of present-day knowledge. The presence of oil and gas in the Permian geosyncline is accounted for by the driving force of the excessive gas pressure due to distillation in the folded zones east of that basin. The preponderance of oil in the western part of the oil fields and the very great preponderance of gas in the eastern part follow from the order of distillation in the course of movements which increased gradually in intensity in each fold; first oil and then gas in quantity, in the order of distillation and in progress up the monocline from east to west. The quality of the oil and the large proportion of gas follow from repeated distillation and migration through long distances.

The absence of salt water from the dry sands in the deeper part of the geosyncline does not find any explanation in this general hypothesis. It is, however, a condition which may reasonably be attributed to migration at a later date, the salt water rising along the limbs of the geosyncline as the gas pressures at higher levels diminished through leakage, erosion, and other superficial factors. If so, the original condition of accumulation would not bear upon the present distribution of the salt water. We may conclude, then, that Peckham's hypothesis of geodynamic distillation of petroleum meets the facts in the Appalachian field.

A study of American and European oil fields along the lines of Peckham's theory obliges us to recognize a great diversity of conditions under which petroleum may be distilled and under which it may migrate. Nowhere, so far as the writer knows, is there an exact parallel to Appalachian conditions. This was to be expected, for the petroleums of the Appalachian fields present peculiar characteristics, and the Appalachian folding, was almost unique in respect to the character and dynamics of deformation.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

DYE DEVELOPMENTS.

In a recent issue of the *Wall Street Journal* the statement is made that one of the dye manufacturing concerns has already lost a very large sum as a result of its effort to give America a domestic dye industry. The money expended cannot be considered lost if it leads eventually to the establishment of a dye manufacturing business, for it is but a fraction of what must be spent in developing new colors, perfecting old ones, and carrying on a broad systematic program of research. Indeed, the statement is made that one concern invested 800,000 in perfecting a single dye stuff. The question therefore continues to be not what it will cost, but whether the country is prepared to give the kind of support to such enterprise which justifies such large expenditures and attracts the necessary capital at the present stage of development.

In a bulletin issued by the American Chemical Society, Dr. Charles H. Herty, who has just returned from Paris where he was sent with the approval of President Wilson to make certain investigations relative to the dye trade, makes the statement that Germany stands ready again to seize the dye trade of the world and to stifle American competition unless adequate legislation is provided. As has been frequently pointed out 75% to 80% of the necessary dyes are available here. Four per cent of the missing dyes commonly called "vat" dyes are particularly desired by the cotton trade, and it is understood that Dr. Herty was sent abroad to determine what could be done to secure enough of these dyes for the use of American manufacturers until American dye stuffs of this type are ready and on conditions that would not pledge the American consumer to a long-time contract.

According to the terms of the peace treaty, 40,000 tons of German dyes, valued at about $70,000,000, had been impounded, and in addition to this quantity, some 6,500 tons had been produced from the daily output, and these the Germans had for free sale under license from the Rhineland Commission. American consumers are permitted to import a portion of these dyes. To quote Dr. Herty: "The threat to the American dye interests, that is, both consumers and producers, lies in the fact that until American manufacturers can supply all of America's needs, Germany can charge extortionate prices for these dyes which we do not manufacture. She is manufacturing dyes on a large scale and because of the present low value of the mark, she will be able to underbid the American dye producer in an open competitive market. The only solution of this problem is legislation by Congress and the introduction of a license system until the American manufacturers are able to supply all our needs and to meet the competition of Germany."

The great Badische plant had smoke issuing from twelve of its fourteen chimneys on October 30th and the dye works on the banks of the Rhine, which represent the greatest factories in Germany, are producing dyes in large quantities. The directors of the Badische plant are confident that they are going to get back their old American business through the medium of their former agents, and state that the lines have already broken and that they have in hand orders from individual consumers in the United States with the authority from the United States Government to ship supplies through their American agents to the consumer.

To again quote Dr. Herty: "The same confidence characterizes the industrial German as had been recorded by the military German in his first advance through Belgium, the same utter contempt shown of American capacity to do things as was revealed during 1917. But 1918 showed that the German had missed his guess and I make the prediction that he has missed it again. Only one thing is needed to insure the correctness of that prediction, namely that the mass of our people understand just what the situation is. Such an understanding will reflect itself in sympathetic protective legislation, and time will do the rest, for the American chemist needs only time to forge the missing links in the chain of a complete self-sustained dye industry."

It would seem therefore that the industrial war is on and we will do well to consider the resources of our antagonist. Germany faces a winter in which the coal supply may become a very serious factor. Transportation problems confront her and the German seems worried over the situation created by the seizure of those patents through which he had for so many years successfully throttled American industry, although he agreed in signing the treaty of peace that these seizures were valid. But notwithstanding these handicaps, the German dye manufacturer is strong today. He has been able to keep the personnel of his plants intact, his plants are in prime condition and even greater than before the war, he has the determination to regain his markets, and it would be an error to underestimate his ability and fighting strength.

Twenty years ago a Swiss professor predicted that some day the synthetic dye industry would flourish in the United States because it is the natural home of that industry, and it appears that time and needful legislation can combine to fulfill the prophecy.

Dr. Herty stated that arrangements had already been made to have sufficient vat dyes in this country by the first of next year to meet the immediate requirements of the American manufacturers and meanwhile ample preparations are being made by American producers to eventually cover American needs. But during this preliminary stage favorable legislation is absolutely essential and even those manufacturers who have always contended for low tariff or free trade principles, seem convinced that the only safe way to insure to America the one industry which above all others should result from the world war is by the enactment into law of the legislation now in Congress.

INDUSTRIAL POISONING.

In the *Journal of Industrial Hygiene*, Dr. Alice Hamilton of the United States Bureau of Labor Statistics, and Assistant Professor of Industrial Medicine at Harvard Medical School, discusses industrial poisoning by compounds of the aromatic series. The study reported embraces benzene and benzene derivatives, nitro-benzene, aniline, and dye manufacture.

The danger from contact with benzene, which is absorbed in the higher boiling oils, during the coking process, which are afterwards subjected to fractional distillation, begins in the distilling house, and while ordinarily there is no danger of industrial poisoning, any accidents which result in a spill or which necessitates repair work, are attended with much danger. Dr. Hamilton cites the case of a man who was drawing off water from the bottom of the benzene settling tanks. To do this he had to stoop under the tanks and while he was supposed to close the valve as soon as benzene began to flow, he apparently was slow in doing this and the fumes of benzene began to escape. Becoming dazed, he started to leave without turning off the benzene, but collapsed on the floor. Two men went to his rescue, but in carrying him up stairs one of them was overcome, fell and broke his neck. The workman was afterward revived.

Since benzene is used in so many industries, for example, as a solvent for rubber, in the paint and varnish trade, in coal tar paint, and as a raw material for making phenol and many intermediates, it is well to become acquainted with its effects. "In benzene intoxication the brain and spinal cord contain relatively more of the poison than any other structures, probably because of the great solubility of benzene in fats and fatlike bodies, such as the lipoids of the nervous system. The effect on the blood is marked and characteristic. There is an anaemia of the aplastic type and a great diminution of the white corpuscles. Capillary hemorrhages under the skin and mucous membranes are so common that the Germans call this form of poisoning "Blutfleckenkrankheit."

The action of the nitro and amido derivatives of benzene, used principally in the production of dyes, perfumes, drugs, and explosives, resembles that of benzene itself, although they do not produce the same effect on the blood cells. Mononitrobenzene is regarded as distinctly more dangerous than aniline, although there is not nearly so much poisoning from nitrobenzene because the work does not involve so much exposure as in the case of aniline. However, when it does occur it is much more likely to be fatal or to produce a longer period of disability than does aniline.

One of the symptoms of aniline and nitrobenzene poisoning is the deep blue color of lips and tongue with headache, slight dizziness, and difficulty in swallowing. The rubber industry used to be the greatest source of aniline poisoning, but the dye industry has displaced it. Aniline has been largely replaced by a solid aniline formaldehyde in rubber compounding and this does not appear to cause industrial poisoning.

The production of dyes on the present large scale presents another interesting field of investigation, for not only are benzene, nitrobenzene, and aniline used in great quantity, but there are a great number of derivatives, some of which may have a toxic action on the skin, the central nervous system, or the blood, or all three. The toxicity of the substances employed depends somewhat upon their physical condition, that is, whether solid or liquid, and to what extent they are volatile. In some instances the degree of toxicity can be estimated from their chemical content, for it is known that the entrance of chlorine into a fatty compound may be expected to increase its toxicity, but the benzene series appears to be little, if any, affected by the entrance of chlorine. Nitration, however, produces a decidedly poisonous product, that is, nitrobenzene and nitrochlorbenzene are much more poisonous than benzene and chlorbenzene. Sulphonation renders a compound non-toxic. For example, as soon as aniline is sulphonated it ceases to be troublesome. The introduction of an alkyl group lessens toxicity, dimethylaniline being less poisonous than aniline, while the HO group renders all members of the benzene series more poisonous. The same group changes alcohols to harmless glycols and glycerols.

Doubtless with the continued development of our chemical industry, the extent to which industrial poisoning is studied will naturally increase to the direct benefit of those engaged.

CHEMISTS' FIRST AID TREATMENT.

DR. PAUL N. LEACH has contributed a valuable series of articles on this subject to *the Chicago Chemical Bulletin* which has now reprinted them in the form of a pamphlet. In many chemical plants the chemist is regarded as the proper person to administer first aid treatment in the absence of a physician, and the difficulty which some people experience in distinguishing between the training of a pharmacist and a chemist may be in a measure responsible for that condition. The average chemist is not qualified to diagnose and consequently cannot efficietly administer treatment. He is unfamiliar with the action of most drugs, may not be familiar with bacteriology and the necessity for complete sterilization of instruments and materials used, and altogether should not be expected to perform the sort of work which a nurse or other properly trained person might. However, the chemist will continue to be called upon for aid and the pamphlet in question therefore will be of great assistance to him.

The emergency treatment of burns, abrasions, bruises, antidotes for poisons, particularly those of a chemical nature, and the proper course of procedure in the treatment of internal conditions is given.

FOOD AND NUTRITION.

A COMMITTEE on Food and Nutrition has been formed under the Division of Biology and Agriculture of the National Research Council, the objects being:

(1) To promote scientific research upon the nutrition of men and of animals, especially animals of agricultural importance, and to bring about closer relations between the two fields of work.

(2) To promote the study of the economic aspects of nutrition, that is, the study of national and international as distinguished from personal nutrition.

(3) Pending the possible establishment of a National Institute of Nutrition, to act as an unofficial clearing house for existing research institutions and to promote and coördinate both American and foreign research.

(4) To promote sane and authoritative extension and propaganda work in the interest of better nutrition.

The methods to be employed in the proposed studies of course differ with the subjects in hand, but coöperation with all existing agencies is very necessary and the first work will be the preparation of a broad program of research in both human and animal nutrition, emphasizing especially the gaps in our present knowledge, with the suggestion of problems of the most immediate importance.

Some of the questions in animal nutrition which are most significant have been arranged by Dr. E. B. Forbes, Chief of the Department of Nutrition, Ohio Agricultural Experiment Station, and a member of the committee, as follows:

(1) The influence of varying proportions of grain to roughage on the rate and character of the growing of cattle.

(2) The influence of the rate of growth on the character of the increase in cattle and swine, that is, the point should be determined at which the protein increase reaches its maximum.

(3) The influence of fertilizers applied to pastures on the skeletal development of calves and colts pastured thereon.

(4) The feeding and management of swine, with reference to the specific effects of feeds, especially of peanuts, on the chemical composition and physical constants of the body fat.

(5) Methods of utilization of the solids of butter, milk and whey.

(6) The development of a system of selective improvement of meat animals based upon the records of efficiency in the utilization of food.

There are many other questions of equal importance and those contemplated in studies relative to human nutrition form an equally large field for intensive research. Studies of this character initiated at this time and consistently sustained can be expected to provide data which is essential in considering our present economic problems in times of peace as well as of those of future wars in which foods may be expected to again play a dominating part.

COTTON LINTERS.

WHILE there is a comparative shortage of long staple cotton due to the inroads of the boll weevil and the new demands, estimated to be equivalent to 500,000 bales annually for cord tires alone in this country, there is an excess of short fibers and particularly of cotton linters.

Before the war about fifty pounds of linters were removed from each ton of cotton seed, but the war time need for cellulose, to be used in producing nitrocellulose, greatly increased the amount of linters produced per ton of seed and the Government finally stipulated a quantity which would be considered good practice. Now that the need for nitrocellu-

lose has diminished, there is a large surplus which normally would go to waste and we have therefore another problem for the chemist.

The Forest Products Laboratory has demonstrated that a good grade of paper can be made from this material and the pulp which could be supplied from this source would amount to many thousands of tons annually. The paper which has been produced is of a quality which would compete with or at least supplement the ordinary grades of rag stock paper and could probably be produced at an attractive price. This is especially true at this time when there appears to be a world shortage of rags for paper stock. Normally the United States is a large importer of rags from Europe, but the scarcity of fibers there and lack of transportation has curtailed this source, and in the interim it is hoped that a satisfactory method can be worked out for using what would otherwise be wasted, thus adding another item to the list of those on which the United States is self-contained.

The campaign to exterminate the cotton boll weevil continues with some encouragement through the use of calcium arsenate in various parts of the cotton belt, particularly in Louisiana. While it has been feared that the dusting of the plant with this poison at sufficiently frequent intervals to be effective would be considered a large item of expense, there are planters who testify that the actual expense is wholly justified and, of course, if the difference is between an acre which produces nothing due to weevil infection, and an acre which has been dusted and then yields a bale of cotton, a large cost can be justified.

The experiments have not been finished, but will be given continuous support. It is believed that the death of the weevil comes from poison present when he drinks the dew which has come in contact with the calcium arsenate.

CHEMICAL WORK AT THE FOREST PRODUCTS LABORATORY.

This laboratory is maintained by the United States Forest Service in coöperation with the University of Wisconsin and at the present time the station numbers about two hundred. The work is going forward under five sections, namely, Derived Products, Preservation, Pulp and Paper, Timber Mechanics, and Timber Physics. The equipment is unique, although not as extensive as some of the enthusiasas would like to have it.

Under Derived Products chemical studies of many kinds are made on naval stores, hardwood and soft wood, distillation products and processes, the manufacture of ethyl alcohol from wood, the analysis of wood preservatives, investigations of extraction processes and products, and similar studies.

Preservation of wood against fire and decay, the development of glues of various types for ply work and joint work, the perfection of specifications and processes for aircraft propeller manufacture, and the study of specifications and processes of manufacture of ply wood, constitute the principal activities of the Section on Preservation. In the preservation of wood, particularly railroad ties, against decay, zinc chloride plays a very important part and the question of the rapidity with which zinc is removed from the tie by leeching is a very pertinent one. The work done on this subject indicates that the presence of even comparatively large amounts of zinc in treated material does not necessarily mean that the wood is protected against decay, unless a sufficient amount of acid is also shown to be present. Unfortunately, our present methods make it possible for the chloride radical to be drawn from the wood by leeching faster than the zinc radical. Much of the work that has been done on the glues and ply wood is of importance to the veneer and furniture manufacturers and consequently is being continued for that purpose, if for no other.

The Section on Pulp and Paper carries on studies in all phases of pulp and paper manufacture, including investigations into the availability of various American woods for pulp purposes.

The Timber Mechanics Section, as the name implies, tests the mechanical properties of wood, studies the effect of defects upon its strength, the development of built-up construction, the improvement of shipping containers of all kinds, the effects of preservatives, kiln drying and other processes upon the properties of wood.

Under Timber Physics there is placed the study of the fundamental principles of the drying of wood, the development of commercial drying methods, and the determination of proper drying schedules of all American woods of importance.

The results of the laboratory's work are made available to the public through the publication of progress reports and final conclusions, supported by necessary data as rapidly as study upon the various phases of the problems can be completed.

BRITISH RESEARCH ASSOCIATIONS.

The British Science Guild, 199 Piccadilly, W. 1, has brought out an interesting volume entitled "British Scientific Projects Exhibition, July 1 to August 5." The war work at universities and other institutions constitutes one chapter; that done in the laboratories of fourteen industrial establishments another; the third describes the progress of the formation of industrial research associations; the fourth lists an interesting collection of scientific and technical books; and the remainder of the volume is given over to a detailed description of the exhibits.

The research associations are of perhaps the most interest to American readers. As has been pointed out previously, they are formed under the Department of Scientific and Industrial Research of the Government, which has at its disposal a fund of one million pounds with which to meet the Government's share in the research work of these associations on a pound for pound basis. Eight of these associations have been incorporated, namely, boot, shoe, and allied trades; cotton; sugar; motor and allied manufacturers; photographic; Portland cement; woolen and worsted industry; and scientific instrument industry.

A like number have been approved, not licensed as yet. These cover India rubber; iron manufacturers; musical insruments; Scottish shale oil; linen; glass; non-ferrous metals; and chocolate, cocoa and jam.

Arrangements for similar associations to cover aircraft and refractory materials are nearing completion, while seven other industries are engaged in drafting articles of association. The latter are: silk; pottery; leather; laundry; master bakers and confectioners; engineering and shipbuilding, and those interested in the lighter manufacturing processes on metals.

As an indication of the work covered by such associations, the following quotation is made from the prospectus of the British Research Association for the Woolen and Worsted Industries:

"The object of the association is to establish, in coöperation with the Government Department of Scientific and Industrial Research, a national scheme for the scientific investigation, either by its own officers or by the universities, technical schools and other institutions, of the problems arising in the woolen and worsted industries, and to encourage and improve the technical education of persons who are or may be engaged in the industries."

The association has published an interesting pamphlet entitled "Scientific Research in Relation to the Woolen and Worsted Industries," in which emphasis is placed upon the objects of research, the methods for research, the cost which is based upon the capital stock of the contributing firms, and the effect of research upon industry. We quote from this last chapter:

"There is first of all the direct effect. A full knowledge, widespread through the industry, of the principles underlying

works and mill practice will enable us to look forward to the future without dread, to meet the vicissitudes of fortune, and to 'greet the unseen with a cheer.' Surely this will be no small gain. It should be emphasized that improvement in machinery and the introduction of more scientific processes are not likely to have the effect of diminishing the number of persons engaged in a well-organized industry. Carlyle pointed out long ago that in his day the number of bare backs was greater than the number of shirts available to cover them, and this is still true. In the language of the economist, the demand for clothing is not yet satisfied. Every improvement in the method of producing clothing will have one of two results: either it makes the goods more cheaply or it makes them better. In either case both labor and capital, to use the common terms, are likely to benefit.

"There are other indirect gains. . . . An industry conducted on scientific lines attracts a better type of worker. . . . Everyone who begins to have experience in industrial research at once looks at the industry from a new standpoint. . . . What they have looked upon as a daily round of mechanical operations pursued solely for the sake of making a iving, is in fact an entrancing subject of study. What man is more fortunate than he who is daily absorbed in an occupation in which he has an interest? This applies both to employers and employes."

BRITISH ENGINEERING STANDARDS ASSOCIATION SPECIFICATIONS.

THE Secretary of the Canadian Engineering Standards Association, Ottawa, announces that some of the publications of the British Association are now for sale at their office. These publications include: An Interim Memorandum on French Metric Screw Threads for Aircraft Purposes; British Standard Tables of Pipe Flanges; Specifications for Structural Steel; British Standard Pipe Threads for Iron or Steel Pipes and Tubes; Specifications for Electricity Meters; Specifications for Cast-iron Spigot and Socket Flue or Smoke Pipes; Standard Rules for Electric Machinery; Report on British Standard Fine Screw Threads and their Tolerances; and the following sets of specifications: for cast-iron pipes, for hydraulic power, for keys and key ways, for sizes of broken stone and chippings, for salt glazed ware pipes, for charging plug and socket, for vehicles run by electric secondary batteries, wrought steel for automobiles, starters for electric motors and for electric cut-outs for low pressure type "O." There is further a report on the British standard dimensions for spark plugs, for internal combustion engines, a report on standard dimensions of wheel rims and tire bands for solid rubber tires for automobiles, British standard nomenclature of tars, pitches, bitumens, and asphalts, when used for road purposes, and British standard specifications for tar and pitch for road purposes.

WELDING THE SHIPS.

THE speed with which the German ships in American ports were prepared for trans-Atlantic duty is not to be looked upon as proof that the damage done was inconsiderable, but due to the high degree of skill attained in welding operations in this country, and to the fact that the German, in his customary methodical manner, carried out his orders so that the damage on each ship was essentially identical. Under these circumstances each ship did not present an entirely new problem, but the work was made easier and could be done with greater rapidity because the experience gained on one job fitted exactly into the requirements on the next.

Welding has become a fine art and chemistry shares in its present perfection. Modern metal compositions require high temperatures and the masses of metals used in some repairs are quite beyond what was considered possible but a few years ago.

In some instances the intense heat of the oxyhydrogen flame answers, but more recently the oxyacetylene torch has been preferred where a welding over comparatively small areas is required. The well-known thermit process where a chemical reaction both produces the required temperature and supplies the molten metal, has held first place almost undisputed in large scale repairs.

In the fabrication of steel ships electric welding proved to be of the utmost importance, helping to accomplish what would otherwise have been impossible. The American Bureau of Welding has taken an active part in this work and has directed much of the research on electric welding methods.

In aluminum welding, where large holes are to be filled, a surface of galvanized iron is sometimes provided to act as a chilling agent, causing the filler to cool and harden prematurely, thereby preventing it from contracting after the weld is finished. Galvanized iron is well suited to the purpose, since it peels away from the aluminum with ease after the weld has been finished and cooled. The welding of aluminum requires great skill, one of the difficulties to be overcome being the oxide film which forms rapidly on molten aluminum. A flux has proven its worth in preventing the formation of this film, thus allowing the aluminum to run together and forming a suitable weld. Before the flux came into general use for aluminum welding, it was almost impossible to build up the parts as desired, but this is now readily accomplished.

Spot welding has already taken the place of riveting for a great deal of fabricated material, especially sheet metal work.

NEW METHOD OF CHEMICAL ANALYSIS.

A METHOD of analysis is described by A. W. Hull in the *Journal of the American Chemical Society*, based on Debye and Scherrer's X-ray spectroscopy of so-called amorphous substances. In this method X-rays, after passing through suitable absorbing screens to render the beam homogenous, and through two suitable slits, are allowed to fall on a small cylindrical tube containing the powdered substance to be analysed. The "reflected" X-rays are received on a cylindrical photographic film. By comparing with similar photographs of known elements and compounds the photographic record obtained in this way, it is possible to distinguish the constituent compounds in the unknown powder.—From *Science Abstracts.*

INFLUENCE OF THE AGE OF THE COW ON THE COMPOSITION AND PROPERTIES OF MILK AND MILK FAT.

DATA obtained from the records of the Jersey, Holstein, and Ayrshire herds kept at the Missouri station show that the average variation in the percentage of milk fat from year to year is not large, with Jerseys the percentage of fat rising slightly in the second or third lactation period and then declining slowly as age progressed, while with the two other breeds the highest percentage of fat generally occurred in the first lactation period the curve then gradually declining. The milk of cows from 11 to 19 years old showed no abnormalities in physical or chemical constituents, and butter made from a cow 19 years old and in her thirteenth lactation period "was pronounced to be of excellent quality, and kept for a period of three months at a temperature of 8° to 10° without showing any marked deterioration."—From *Chemical Abstracts.*

GLAUBER'S SALT IN SIBERIAN LAKES.

THE following is an estimate of supplies of precipitated Glauber's salt in some of the Siberian lakes: (1) The Great Marmyshansk Lake, 144,000,000 poods (2,600,000 short tons) of crystalline salt ($Na_2SO_4 10H_2O$) and 22,000,000 poods (397,210 short tons) of evaporated Glauber's salt; (2) Little Marmyshansk Lake, 25,000,000 poods (451,400 short tons) of crystalline salt; (3) Lake Tuskal (Minusinsk district)—up to 100,000,000 poods (1,805,500 tons) of crystalline salt; (4) Lake Varche (Minusinsk district)—up to 100,000,000 poods (1,805,500 tons) of precipitated crystaline salt and an enormous quantity of Glauber's salt in solution.—From *Commerce Reports.*

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

INTRODUCTION

THE readers of the SCIENTIFIC AMERICAN MONTHLY are probably better informed than the majority of people concerning the work done by the Bureau of Standards at Washington, but, even in their case, a short statement of the very broad field of scientific research covered by the activities of that Bureau may be of interst.

The usual idea of a standardizing institution seems to be that of a Bureau concerning itself with the comparison of weights and measures. Such was, in fact, the original work of this character undertaken in the United States, and from it the present Bureau of Standards has grown. The importance of exact fundamental standards was recognized in the earliest times, and probably dates from the beginning of civilization itself. Certain recommendatons concerning the establishment of standard weghts and measures were made at the time of the founding of our present government. Little however, was actually accomplished in the United States until the founding of the present National Bureau of Standards by an act of Congress in 1901.

Standardization, as understood at present, includes much more than the standardization of weights and measures, and it will give the reader some idea of the great variety of the work comprehended by this term to list the various kinds of standards with which the Bureau deals. These include: Standards of measurement, such as units of length, mass, and time; physical constants, as an example of which may be mentioned the latent heat of vaporization of water; standards of quality, which are concerned mainly with the specification of materials; standards of performance, such as the ratings given to engines, electrical apparatus, instruments, etc., and standards of practice, among which may be mentioned the specification of requirements for gas and electric service in our cities.

Work in connection with each of these standards requires the employment of a large corps of experts and calls into requisition all of our knowledge in the fields of physics, chemistry, and engineering. The organization of the Bureau is based upon the different kinds of work which it performs rather than upon the various kinds of standards. Its scientific work is divided into nine divisions, as follows: electricity, weights and measures, heat and thermometry, optics, chemistry, mechanical appliances, structural and miscellaneous materials, metallurgy, and ceramics.

From time to time, the Bureau will endeavor to supply certain notes on current researches which will be of interest to the readers of this journal. Those submitted this month are representative of the work now being carried on and in which the Bureau is coöperating with the various industries.

INVESTIGATION OF STRESSES IN REINFORCED CONCRETE FLOORS.

The use of reinforced concrete and tile for the construction of floors in large buildings has become very common of late years, and with the increasing use of these floors, it is essential to determine accurately the stresses to which they are subjected when called upon to withstand heavy loads. The theory of the behavior of such types of construction is not at present completely understood. The load upon any panel affects not only that panel, but all the surrounding panels, and the interactions of members thus developed is so complicated as almost to defy analysis. This makes it necessary to base designs largely upon empirical formulae, arrived at as the result of tests. Certain properties of the materials used enable the engineer to determine with a fair degree of accuracy the stresses to which the floor is subjected under various conditions of load. Materials under tension stretch or elongate, while those subjected to compression become shorter, and this change in length has been established for various materials. Therefore, if the elongation or shortening of the materials in a reinforced concrete floor have been measured, the amount of tension and compression in the materials may be calculated. In such a problem, it is assumed that the steel reinforcement carries all the tension while the concrete withstands the compression.

Since the steel reinforcement is embedded in the concrete, holes are drilled in the concrete a certain distance apart exposing the steel reinforcing bar for the purpose of making measurements, and with a very fine drill two holes are then made in the bar itself. The distance between these holes is approximately the desired gage length, say 8 inches. Similarly, for the purpose of measuring the compression, holes are drilled in the concrete about 8 inches apart and steel plugs inserted. In these plugs the very small holes for the instrument are drilled, as was the case with the reinforcement bar. We have just stated that these gage holes are made a specified distance apart; this distance is approximately equal to the zero position of two points on an instrument known as the strain gage. The strain gage is made up of a fixed point and a movable point pivoted to a metal frame. The movable point actuates through multiplying levers a hand on a graduated dial. A change in length of .0001 inch in the gage length may be thus detected.

The usual way of conducting a test of a concrete and tile floor is to arrange the desired gage openings in the steel and concrete at all points at which the stresses are to be determined. The strain gage readings are then taken and recorded on the data sheet when the floor is subjected to no load. Of course, if the holes in the steel and concrete had been drilled with absolute accuracy, they would all be exactly 8 inches apart, and there would be no need of taking a set of zero readings. Such a case never occurs in practice. The floor is then loaded in any desired way, with cement or other material and the measurements with the strain gage repeated. These will show a difference in length, both in the steel and concrete; the difference amounting to the total elongation or shortening in the gage length of 8 inches. The unit change in length will be this total change divided by the gage length. It is the usual practice to apply the load to the floor in small increments, so that when the data are worked up, curves may be drawn showing the deformations at different percentages of the total load. After the maximum load has been applied, this may be removed and zero readings again taken to show whether the material has received any permanent deformation. Sometimes, still another set of readings is taken several days after the removal of the load, as the material may recover very gradually. The accuracy of the readings obtained with a strain gage depends to a great extent upon the experience and skill of the operator, and one man should take all of a given set of readings during one test. Having obtained the readings, it still may not appear quite clear how the stresses in the materials can be calculated. The explanation, however, is simple. Experiments have shown how much a steel of given quality and cross section will elongate under different loads. The same applies to the compression of concrete. Knowing the lengthening and shortening, we are able to figure the unit stress at that time.

The deflection of the floor in a vertical direction under various loads is determined by measurements between points

on the floor slab under test and other points directly above or below them.

The Bureau of Standards has recently undertaken one of the largest tests of this type of floor so far carried on. The work is being conducted on a large test slab recently erected for a large manufacturing company located in Ohio. The floor slab which is to be tested is built of reinforced hollow tiles with concrete ribs between them and a two-way system of reinforcement. In this construction, the steel reinforcement is placed sixteen inches on centers, in each of the two directions parallel to the edges of the panel. In the center of each of the sixteen inch squares formed by the intersection of the reinforcement bars is placed a hollow tile, 12 inches square, of a depth equal to the nominal thickness of the floor panel. In the present case, six-cell hollow tiles, 6 inches in depth, are used. After these tiles are set in position, the whole area is filled with concrete flush with the tops of the tiles. The adhesion between the tiles and concrete is depended upon to give unity of action.

The first slab, as built for the above firm, consists of eighteen panels. Six panels are each 16′ × 16′; six are 16′ × 19′ — 3″, and six are 16′ × 22′ — 6″. Each group contains one panel having a cantilever. These panels are supported on columns of the ordinary story height used in buildings.

The supporting columns for the slab were poured five days in advance of the slab, and the pouring of the slab itself required another five days. From each day's pouring 6 test samples were takan. Three of these samples are to be broken at the age of 30 days, and the others at intervals of 5 days thereafter. From the results, curves will be plotted to determine the time when the concrete attains the strength of 2,000 pounds per square inch in compression, and as soon after this date as possible the load tests of the slab will be started. Numerous steel plugs have been set in the concrete and tile for taking strain gage readings, as described above. Two large control beams and two standard bars 3′ × 3′ × 6″ were moulded from the concrete used in making the slab. These, together with representative specimens of the tile, will be used to obtain preliminary data.

THE BUREAU'S WORK IN THE FIELD OF RADIO COMMUNICATION.

The important work done by this government in the development of apparatus for radio telegraphy and telephony is only now becoming generally known. Information concerning this work was necessarily kept secret during the war, but recently several magazine articles have been published which have dealt with the government's investigations in a popular way. In connection with this development work, the Bureau took an active part and the numerous inquiries which have been received indicate that a few notes on the subject may not be out of place. The principal accomplishments of the war period were the development of the radio direction finder, and the electron tube. The first device is quite a new development and is so constructed that it receives radio waves and at the same time indicates the direction from which they come. During the war, it was very largely used in locating the position of enemy radio stations, both on land and sea. The electron tube may well be said to have revolutionized the art of radio communication and to have made practicable radio telephony. It has enabled American airplane pilots to talk with one another in flight.

Work in connection with the standardizing of these tubes was undertaken in connection with the Signal Corps and research work has been continued with a view to improving their action and increasing the knowledge concerning such devices.

Other investigations included the development of landing signals for airplanes, means for submarine radio communication, detecting devices, and the development of radio measurement. A number of publications, of both a technical and elementary character, were issued by the Bureau, among them being a manual of radio work.

Considerable difficulty has been experienced by airplanes in landing in the dark and in foggy weather. Particularly in war times airplanes are required to fly at high altitudes until they are behind their own lines and can safely descend. The Bureau, as mentioned in the previous paragraph, aided in the development of a system of airplane landing signals by means of which an airplane at high altitudes is able to tell when it is over its own landing field. The work was carried out for the Aerial Mail Service of the Postoffice Department, though it is equally applicable, as stated above, to the aerial service of the military departments.

Radio signals are sent from a transmitting station on the landing field and by means of a direction finder on the airplane the aviator is able to steer toward the source of these signals. On the landing field, there is provided a special kind of coil which emits signals, identical with the radio signals except for the fact that their effect does not extend much beyond the space immediately over the landing field. They are, therfore, heard by the aviator only when he crosses the field. On descending where these signals are loudest, he lands in the middle of the field. These landing signals are produced by the same generating apparatus on the ground as that used for the radio signals and both are received by the aviator with the same apparatus. The signals have been heard at a height as great as 6,400 feet.

PRINCIPLES OF RADIO TRANSMISSION AND RECEPTION WITH ANTENNA AND COIL AERIALS.

The ordinary type of antenna is satisfactory in the case of radio stations where plenty of space is available, such as those ordinarily constructed on land. In the case of airplanes, submarines, and other small vessels, it would be a great advantage to have some more compact form of transmitting and receiving mechanism. The relative advantages of the antenna or usual type of elevated aerial and the so-called coil aerial is an extremely important question and has recently been the subject of an investigation conducted at this Bureau. An article dealing with the work which has been accomplished along these lines was recently delivered in the form of a lecture at a joint meeting of the American Institute of Electrical Engineers and the Institute of Radio Engineers.

As a result of this work, it is now possible to determine by simple calculation the distance at which a given receiving aerial will receive signals from any transmitting aerial when the current in the aerial, its dimensions and the distance between the stations are known. It is obvious that the small coil aerial has many advantages, under the conditions as outlined in the first part of this paragraph, but it is usually not as powerful a transmitting and receiving device as the more common antenna type. The resistance of the coil aerial, however, may be so much lower than that of the antenna that it is equal to it in transmitting and receiving value. This work has brought about a better knowledge of the action of radio waves, a subject which up to this time has been but little understood.

INCREASING THE SPEED AND COLOR SENSITIVENESS OF PHOTOGRAPHIC PLATES.

It is well known that the ordinary photographic plate, when exposed in a camera, does not reproduce exactly what the eye sees. This is because the ordinary plate is affected by only blue, violet, and ultra-violet light to which the eye is relatively insensitive, and is scarcely at all affected by the green and yellow, for which the eye has its maximum sensitivity. These ordinary photographic plates are practically insensitive to red light and are, therefore, handled with safety in light from a ruby lamp. It has long been known, however, that photographic plates may be made sensitive to green, yellow and red light by the admixture of suitable dyes to the emulsions coated on the plates, and so-called orthochromatic and panchromatic plates have been on the market for years. The color sensitivity and speed of these commercial plates are not sufficiently great, however, to make them useful where

only short exposures can be used, as in photography from airplanes. Fortunately, it has been found that, at expense of keeping qualities, photographic plates of speed and color sensitiveness far superior to any commercial plates can be obtained by laboratory methods. A method in use for many years in the photography of spectra consists of bathing an ordinary blue and violet sensitive plate in a dilute solution of photo-sensitizing dyes. This method has been a continuous laboratory practice at the Bureau of Standards since 1913 for spectroscopic investigations and since 1917 a large number of experiments have been made in the use of such plates in aerial photography. The staining bath used in the preparation of these plates consists of a solution of dyestuff in a mixture of water, alcohol and ammonia. The effect of ammonia on the photo-sensitizing dyes was carefully investigated and it was found that the speed and color sensitiveness of commercial plates which have dyes incorporated in the emulsions, could be enormously increased by bathing such plates in a dilute solution of ammonia.

This method of hypersensitizing commercial panchromatic plates has also been used very successfully in aerial photography. For the comparison of different types of photographic plates, a four-lens camera in which various color sensitive plates could be placed behind lenses containing ray filters was used, and the advantages of plates highly sensitive to green, yellow, and red light have been strikingly shown. For example, in addition to the fact that a panchromatic plate reproduces more faithfully what the eye sees, it portrays objects, when exposed behind a ray filter or color screen, which, on account of haze, smoke, etc., would be hidden from an ordinary plate. Furthermore, it also gives different contrasts depending on the nature of the light transmitted to the plate through the filter. The phenomenon of haze penetration by the longer waves is known to most outdoor photographers. The blue sky and red sunset are proof that the blue or short light waves are scattered in the atmosphere and the red or longer waves are more readily transmitted. A red-sensitive photographic plate used in a camera with a red filter in the lens will, therefore, reveal objects which, owing to the obscuring presence of haze or smoke, fail to make any impression whatsoever on an ordinary blue-sensitive plate. To obtain these long-wave advantages of haze penetration and contrast, the photographic plates must have the greatest possible sensitiveness to yellow, orange, and red light if the lengths of exposure are necessarily short, either on account of rapidly moving objects, or, if the camera itself is in rapid motion, as is the case in aerial photography. A brief circular describing the practice of the Bureau of Standards in (1) bathing ordinary dry plates in solutions of photo-sensitizing dyes, and (2) treating commercially dyed plates with dilute ammonia has been prepared. Instrucions are given in the preparation of color sensitive photographic plates of maximum speed.

Progress of Science in America

Notes Furnished by the National Academy of Science

THE autumn meeting of the National Academy of Sciences was held at Yale University, New Haven, Connecticut, November 10 and 11. There were about 50 members of the Academy in attendance. An exceptionally pleasant feature of the meeting was the reception tendered by the President of Yale University and Mrs. Hadley at the Yale School of Fine Arts, where the famous Trumbull portraits of Washington and Hamilton and a very remarkable collection of old Italian paintings are preserved.

The luncheons at the New Haven Lawn Club, and an expedition to the laboratories of the Connecticut Agricultural Experiment Station were much enjoyed. At the Experiment Station papers were presented on the relation of particular vitamines to nutrition, and opportunity was given to see the colony of several hundred white rats on which the experiments are being conducted.

At the dinner of the Academy on November 11 the Daniel Giraud Elliot Medal was presented to Mr. C. William Beebe of the New York Zoological Park for his "Monograph of the Pheasants." The speech of presentation was made by Prof. Osborn of the American Museum, New York, who laid before the Academy the beautifully printed and illustrated monograph of Mr. Beebe. In an after dinner speech ex-President Taft expressed optimism with regard to the future of industrial relations of the United States and told amusing reminiscences of association with Roosevelt and others.

At the business meeting of the Academy the Henry Draper Gold Medal was awarded to Alfred Fowler, F.R.S., Professor of Astrophysics, Imperial College, South Kensington, London, for his researches in spectroscopy, relating especially to the spectra of terrestrial compounds and their occurrence in sunspots, and to stars of Secchi's Type III.

Announcement was made regarding the Mary Clark Thompson gift of $10,000 to establish a fund to be applied to a gold medal to be awarded annually by the Academy for the most important services to geology and paleontology.

The public sessions for the reading of papers were held in the Osborn Zoological Laboratory. Among papers of special interest was that of Prof. R. A. Millikan, of the University of Chicago, who showed photographs of the extreme ultra-violet spectrum extending as far as wave length 252 Angström units. The furthest extension hitherto was made by Lyman who reached the wave length 510 Angström units. In the spectrum of carbon Prof. Millikan found three lines which from various kinds of evidence he believes to be the same as the three lines of the L spectrum hitherto associated with the famous work of Mosely on the X-ray spectra of the elements. If Prof. Millikan's conclusion is confirmed the long gap between the X-ray spectra of the elements and their visible spectra will again be bridged. Certain lines of helium were found in the carbon spectrum which were so strong and persistent that the impression was produced in Prof. Millikan's mind that these were due to the breaking up of carbon in the intense spark, employed as the radiation source, with the formation of helium. This would be comparable to the well-known disintegration of radium with similar evolution of helium.

Dr. Simon Flexner gave a most interesting description of the past history, progress of the present epidemic, and symptoms of the disease, frequently spoken of as "sleeping sickness," which has appeared within about a year in the United States for the first time. The cause, method of propagation, and means of cure of this disease are as yet unknown, but Dr. Flexner expressed great hope that the efforts of investigators would enable these fundamental features to be discovered so that future epidemics might be checked.

Papers by Prof. E. B. Wilson and Dr. Leigh Page led to a discussion of the announcement recently made in England that the results of the British eclipse expeditions to Brazil and West Africa had confirmed the existence of a deflection of the light of the stars passing by the sun of the same magnitude as that predicted by Einstein's generalized theory of relativity. The discussion developed the point of view, es-

pecially among the experimental physicists present, that it is not necessary to suppose that the deviation of the light observed is really a proof of the soundness of the theory of relativity. Several other causes, as diffraction and refraction, might be operative to produce the small bending of the star rays seen. The impression prevailed that, so far as observations of any kind have yet gone, no one is compelled to adopt the difficult and obscure theory of relativity in place of other explanations of phenomena, unless he has the type of mind that prefers it.

Dr. Davenport presented results of medical examinations of drafted men. Statistical investigations had been completed as to the geographical distribution of defects of different kinds. Very curious distribution of certain kinds of sickness, malformation, and injuries was shown by maps. A discussion of the relative prevalence of these defects in drafted men from city and country districts showed in general that the healthfulness of the two were almost equal, although certain diseases appeared to be prevailingly country diseases and others prevailingly city diseases.

Dr. James B. Murphy showed that accompanying cancer grafts in immune animals there occurs a general increase in the circulating lymphocytes and hyperplasia of the lymphoid tissue. When the lymphoid tissue of immune animals was destroyed, the immunity was annulled. Two methods of increasing the lymphocytes have been found, namely, diffuse small doses of X-rays and dry heat. Mice with lymphocytosis induced by these methods have a high degree of resistance to transplanted cancer. Mice with spontaneous cancers treated by these agents show increased resistance to replants of their own tumors. The results afford grounds for hope of human application.

Dr. Hidayo Noguchi described his work in connection with the sanitary commission to study yellow fever at Guayaquil, Ecuador. Dr. Noguchi has been successful in producing yellow fever in guinea pigs and marmosets, and showed by lantern slides many characteristic curves of temperature and other symptoms of yellow fever in these animals. By these means and by special methods of staining he appears to have demonstrated the micro-organism of yellow fever for the first time as a spirochaeta which has hitherto escaped detection because of optical similarity to the medium invaded by it.

Dr. Henry Fairfield Osborn presented lantern slides of restorations of certain of the sauropod dinasaurs. These were given in continuation of his long investigations with his colleagues in these lines. He dwelt particularly on the necessity of studying the muscles and motions of the animals with relation to the most similar lving creatures. A true idea of their forms cannot be gained from skeleton remains alone. He intimated that a thorough understanding of their forms could only be had by such discussion of the animal in motion as might even involve the production of moving pictures in order to reach a satisfactory conclusion.

Dr. C. G. Abbot described a new method of determining the intensity of the solar radiation outside the atmosphere, by means of which the so-called "solar constant of radiation" may be determined by ten minutes of observation and two hours of computation better than it could be obtained before by three hours of observation and fifteen hours of computation. He also exhibited photographs of the total eclipse of May 29, 1919, taken at La Paz, Bolivia.

Dr. E. W. Brown exhibited the first copies to reach this country of his numerical tables of the moon's motion. These are the concrete result of many years of work by himself and his colleagues and may be expected to replace the tables of Hansen which have been used by nautical almanacs for the past sixty years.

ARTIFICIAL HONEY IN GERMANY.

Artificial honey was consumed in Germany in large quantities during the war. Although the conversion of cane sugar into invert sugar is a simple chemical process, the products of different firms were lacking in uniformity, a considerable portion consisting of a thin fluid. For the production of a thick variety the water content and the inversion of the cane sugar are matters of great importance. The water content must not exceed 22 per cent and the inversion must be complete to within 5 per cent. The inversion proceeds best when at least 0.1 per cent of formic acid is present. The strongly acid taste of the product is removed by neutralising with sodium carbonate. The enactment of a law similar to that concerning margarine is recommended in order to prevent confusion between natural and artificial honey in the trade. On economic grounds, thick artificial honey is an indispensable product in Germany.—*From Schweiz. Chem.-Zeit.*, 1919.

CONDITIONS THAT GOVERN STALENESS IN BREAD.

In a pamphlet bearing this title Capt. R. Whymper describes investigations carried out in the British Army bakeries in France during 1917-18. The results are given under four headings: I. Determination and location of losses occurring in the manufacture of bread; II. Conditions that govern staleness in bread. III. Changes occurring in bread with age. IV. The colloid nature of starch pastes, bread crumbs, etc. It was found that the cooling of bread takes place in three stages, namely, the steam period, during which most of the drying-out takes place in a given time; the condensation period, during which the rate of drying is only one-fifth that of the steam period; and the drying period in which the rate of drying is about one-fourth that of the steam period. Loss of moisture from the center of the loaf is inconsiderable until after 100 hours under ordinary conditions, an actual increase being often observed before this time. The zone of drying-out is very narrow in a loaf up to about 100 hours, being about 1 in. inwards from the crust; after 100 hours the moisture diffuses gradually from the center of the loaf, but at so slow a rate that there is always a pronounced difference between the moisture content of the crumb at the center of the loaf and that of the crumb beneath the crust. The loss of water during cooling and drying-out is not responsible for staleness. During the process of becoming stale the soluble extract of the crumb decreases, this decrease being followed after a time by an increase. The quantity of soluble starch in bread crumb diminishes rapidly betwen the sixth and twenty-fourth hours of the cooling period; a similar fall and rise of soluble extract is observed in starch pastes. Staleness may be attributed to deposition of solid starch in the crumb caused by change of temperature during the cooling period and accelerated by the presence of solid starch particles already existing in the crumb. Staleness is also due to polymerisation of starch, which tends to crumble the gelatinous nature of the bread crumb when fresh. Other changes occurring in the proteins of bread crumb may be responsible for staleness, but these have not yet ben investigated.—*From Jour. of the Soc. of Chem. Ind.*

SEA-GRASS FIBRE AS A PACKING MATERIAL

M. Gloess, in the *Bulletin de l'Institut Oceanographique*, mentions the utility of sea-grasses as a packing material in place of wood-wool. The fibers of sea-grass are light, elastic, non-inflammable, odorless and non-rotting; advantages which are of considerable importance when perishable foodstuffs are being packed. It is stated that the elasticity of this material is three times as great as that of wood-wool, which means that notwithstanding the fact that the cost of producion is somewhat higher, the use of sea-grass fibre would be twice as economical as the most economical packing hitherto employed. This material is slightly lighter than wood-wool.—Abstract from *La Nature*, Oct. 11, 1919, by the *Technical Review*.

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THE ART OF THE APOTHECARY—GRINDING QUINQUINA BARK (SEE PAGE 159).

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A ROCKET THAT WILL CARRY TO THE MOON.

THE daily papers, a few weeks ago apprised the public of the fact that Dr. Robert H. Goddard of Clark University, had developed a new form of rocket so far superior to anything now in existence that not only would it carry to the uppermost limits of the earth's atmosphere, but it would actually escape from the earth's attraction. Of course, the newspapers seized upon and featured the statement that the rocket could be fired to the moon.

Had not the announcement of Dr. Goddard's work issued from so reliable a source as the Smithsonian Institution it would not have attracted serious attention. As it was it seriously strained the credulity of the public. Many sober-minded individuals questioned the value of such an attack upon our faithful satellite, and it looked to them like an effort to create a sensation. Some claimed to have found a fallacy in Dr. Goddard's plans. That a rocket could be so improved and refined as to carry to the uppermost reaches of the earth's atmosphere was readily conceded, but to them it was inconceivable that the powder charges could keep on propelling the rocket where there was no air for the gas to act against. Clearly they had a wrong conception of the principle upon which the propulsion of a rocket is based. Had they read Dr. Goddard's complete paper they would have learned that his experiments were conducted *in vacuo* as well as in air and that the velocities obtained *in vacuo* were not much different from those obtained in air. They would also have learned that Dr. Goddard did not begin his research with any Jules Verne idea of a lunar expedition, but solely for the purpose of investigating atmospheric conditions at extreme altitudes. The following quotation from Professor Goddard's paper on the subject show the importance of such an investigation:

"The greatest altitude at which soundings of the atmosphere have been made by balloons, namely, about 20 miles, is but a small fraction of the height to which the atmosphere is supposed to extend. In fact, the most interesting, and in some ways the most important, part of the atmosphere lies in this unexplored region a means of exploring which has, up to the present, not seriously been suggested.

"A few of the more important matters to be investigated in this region are the following: the density, chemical constitution, and temperature of the atmosphere, as well as the height to which it extends. Other problems are the nature of the aurora, and (with apparatus held by gyroscopes in a fixed direction in space) the nature of the α, β, and γ radioactive rays from matter in the sun as well as the ultra-violet spectrum of this body.

"Speculations have been made as to the nature of the upper atmosphere—those by Wegener being, perhaps, the most plausible. By estimating the temperature and percentage composition of the gases present in the atmosphere, Wegener calculates the partial pressures of the constituent gases, and concludes that there are four rather distinct regions or spheres of the atmosphere in which certain gases predominate: the troposphere, in which are the clouds; the stratosphere, predominatingly nitrogen; the hydrogen sphere; and the geocoronium sphere. This highest sphere appears to consist essentially of an element, "geocoronium," a gas undiscovered at the surface of the earth, having a spectrum which is the single aurora line, $557\mu\mu$, and being 0.4 as heavy as hydrogen. The existence of such a gas is in agreement with Nicholson's theory of the atom, and its investigation would, of course, be a matter of considerable importance to astronomy and physics as well as to meteorology. It is of interest to note that the greatest altitude attained by sounding balloons extends but one-third through the second region, or stratosphere."

The search for some means of raising recording apparatus above an altitude of 20 miles led Professor Goddard to develop a theory of rocket action. The problem was to determine the minimum initial mass of an ideal rocket necessary, in order that on continual loss of mass, a final mass of one pound would remain at any desired altitude. The problem was solved by an approximate method, in order to avoid an unsolved problem in the Calculation of Variations. It was found that surprisingly small initial masses would be necessary provided the gases were ejected from the rocket at high velocity, and also provided that most of the rocket consisted of propellant material, because the velocity enters exponentially in the expression of the initial mass. Thus, if the velocity of the ejected gases be increased five fold, the initial mass necessary to reach a given height will be *reduced to the 5th root*, of that required for the lesser velocity.

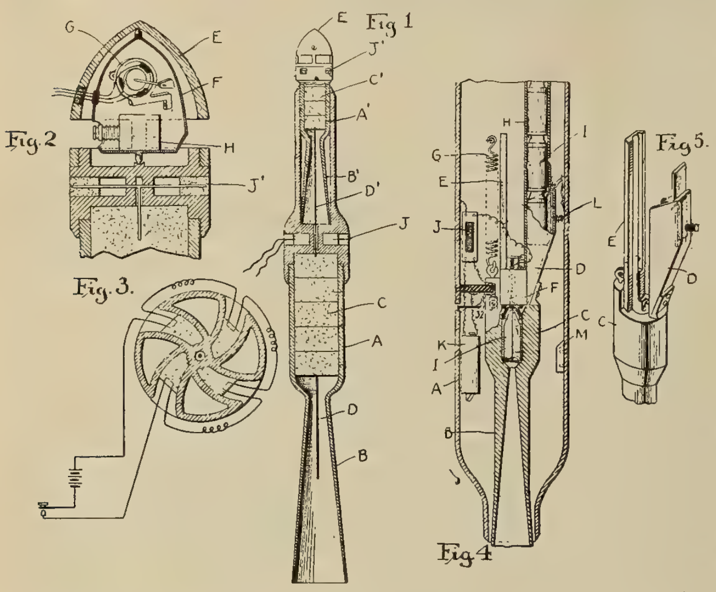
Experiments showed that in an ordinary rocket, the powder constitutes only one-fourth or one-fifth of the total mass and that the average velocity of ejection is about 1,000 feet per second. This is true even of the Coston ship rocket which was found to have a range of a quarter of a mile. The efficiency of the rocket, that is the ratio of the kinetic energy of the expelled gases to the heat energy required, was only two per cent.

In order to increase the velocity of ejection of the gases, charges of smokeless powder were fired in strong steel chambers fitted with tapered nozzles designed to obtain the work of expansion of the gases, as in the De Laval steam turbine. The efficiencies and velocities obtained in this way were remarkably high, the highest efficiency being over 64 per cent, and the average velocity of ejection slightly under 8,000 ft./secs., which exceeds any velocity hitherto attained by

matter in any appreciable amounts. These velocities were proved to be real velocities, and not merely effects due to reaction against the air, by firing the same steel chambers *in vacuo*, and observing the recoil. The velocities obtained in this way were not much different from those obtained in air. It was evident that a heavy steel chamber, such as was used in the experiments, could not compete with the ordinary rocket, even with the high velocities which were obtained.

In order to reduce the weight of the rocket, Dr. Goddard determined to use small charges of explosives fired successively, as in a machine gun, so that the firing chamber would not have to be made of very heavy steel. In this way, most of the mass of the rocket could consist of propellant material,

Several patents have been obtained by Dr. Goddard on his rocket, two of which are illustrated herewith. Figure 1 shows the original design in which the propellant material is contained in mass instead of in separate cartridges. Two rockets are provided, one fitting in the other so that after the



DR. GODDARD'S ROCKET

FIG. 1 to 3, EARLY FORM. FIGS. 4 AND 5, LATEST DESIGN

first has discharged its propellant material, the second will shoot out of it and proceed under its own charge of propellant material. In the figure the main rocket consists of a casing A provided with a tapered nozzle B. The propellant material is shown at C and a fused D extends into the nozzle B, whereby it may be ignited. At the upper end of the casing A, there is an extension in which is fitted the second rocket consisting of casing A', nozzle B' and propellant material C'. The second rocket is provided with a head E which is shown in detail in Figure 2. Within this head is a chamber F mounted on pivots to turn freely, and inside this chamber there is a gyroscope G which may be actuated by an outside source of electricity to set it in motion at high velocity. Below the gyroscope, there is a recording instrument H, which in this case, is shown as a camera. The head E is provided with apertures through which the camera or other recording apparatus may have access to the outside.

In order to keep the rocket on its course it must be rotated at high speed, but the camera chamber is kept from rotation by the gyroscope G. The rocket is rotated by powder charges in radially spiral chambers as shown more clearly in the sectional view, Figure 3. The rocket is set in a standard fitted with ball-bearings to permit it to revolve freely. Then the charges in the chambers J are simultaneously ignited causing the rocket to spin. After sufficient velocity has been obtained the fuse D is lighted and the rocket ascends. When the propellant material C has all been consumed, the fuse D' ignites the propellant material C' in the second rocket. The second rocket then shoots out of the first rocket. When the propellant material C' is all consumed, fire travels through a fuse to a series of spiral radial chambers J', which are filled with propellant material, and these give further spin to the rocket. Parachute devices are provided to bring the parts down to the ground in safety.

The construction shown in Figure 4 is a later development of Dr. Goddard's rocket. The main casing of the rocket is indicated at A and the nozzle B leads from the firing chamber C. Attached to this chamber C at one side is a chute D and a pair of guides E, which slide in grooves in a breech-block F. The construction of the firing chamber is shown in Fig. 5. A spring G holds the firing chamber against the breech block. Just above the chute D there is a magazine H filled with cartridges I. One of these cartridges is shown in the firing chamber in our illustration. When this is fired, the chamber C is forced downward by reaction against the breech block, and a pin L on the chute D coming in contact with a cam M on the casing A releases a new cartridge I and lets it slide into the firing chamber. At the same time, mechanism is set in motion to eject the cartridge shell. The cartridges are successively fired by means of battery K and spark coil J. In a later modification the cartridges are composed almost entirely of a propellant material consisting of an outer shell of compressed smokeless powder covered with a coating of shellac.

Dr. Goddard's experiments showed that it would be possible to raise a mass of one pound to altitudes of 35, 72 and 232 miles by employing initial masses of from 3.6 to 12.6, from 5.1 to 24.3, and from 9.7 to 89.6 pounds, respectively. If a device of the Coston ship rocket type were used instead, the initial masses would be of the order of magnitude of those above raised to the 27th power. Dr. Goddard calls attention to one particular case in which if ship rockets were grouped together in sufficient mass to raise one pound to an altitude of 232 miles, this mass, even neglecting air resistance entirely, would have to be over *six fold greater than the entire mass of the earth.*

As we have stated above, in order to recover the apparatus without damage, a small parachute should be sufficient to insure a safe landing, and Dr. Goddard has obtained a patent upon suitable parachute devices for this purpose. These parachutes would not retard the velocty of the rocket through the tenuous upper starta of the atmosphere, but as denser atmosphere was encountered on the way down the velocity of the falling body would be increasingly retarded until it landed.

Dr. Goddard in his speculations upon the possibility of propelling the rocket to such a distance as to escape the earth's attraction, found that the rocket could start at sea level with a total initial mass of 602 pounds, or from an altitude of 15,000 feet with a mass of 438 pounds, provided the effective velocity was 7,000 ft./sec. and the acceleration 150 ft./sec.^{2}. In order to prove that such an extreme altitude had been reached, he suggests aiming the rocket to strike the dark surface of the moon and providing it with a small mass of flash powder which would be ignited upon impact. He found that a mass of 2.67 pounds of Victor flash powder would be just visible through a telescope of one foot aperture if exploded on the surface of the moon, 220,000 miles distant, and that a mass of 13.82 pounds or less would be strikingly visible. However, as Dr. Goddard says, "this plan of sending a mass of flash powder to the surface of the moon, although a matter of much interest, is not of obvious scientific importance." Calculations show that the total initial mass required to send one pound to the surface of the moon is but slightly less than that required to send it to infinity.

Dr. Goddard's experiments to determine the efficiency of the ordinary rocket and the efficiency of various powders are most interesting. An abstract of that part of his paper which deals with his experimental work is published in the following pages. Mathematical demonstrations and many interesting tables have been omitted owing to limitations of space.

A Method of Reaching Extreme Altitudes*

Experiments with Rockets and Powders

THE following experiments were performed: First, with the object of finding just how inefficient an ordinary rocket is, and secondly, to determine to what extent the efficiency could be increased in a rocket of new design. The term "efficiency" here means the ratio of the kinetic energy of the expelled gases to the heat energy of the powder, the kinetic energy being calculated from the average velocity of ejection, which was obtained indirectly by observations on the *recoil* of the rocket.

EFFICIENCY OF ORDINARY ROCKET.

The average velocity of ejection of the gases expelled from two sizes of ordinary rocket were determined by a ballistic pendulum. The smaller rockets averaged 120 grams, with a powder charge of 23 grams; and the larger, the well-known Coston ship rocket, weighed 640 grams, with a powder charge of 130 grams.

The ballistic pendulum, Fig. 1, was a massive compound

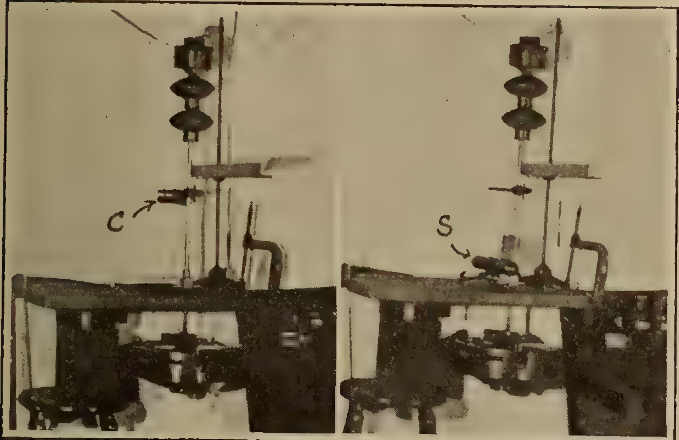


FIG. 1. THE BALLISTIC PENDULUM WITH WHICH THE SMALL ROCKET (C) AND THE LARGE ROCKET (S) WERE TESTED

pendulum, weighing 70.64 Kg. (155 lbs.) with a half period of 4.4 seconds; large compared with the duration of discharge of the rockets. The efficiencies were obtained from the average velocity of ejection of the gases, found by the usual ballistic pendulum method, together with the heat value of the powder of the rockets, obtained by a bomb calorimeter for the writer by a Worcester chemist.

It was found that the efficiency of the ordinary rocket is close to 2 per cent; slightly less for the smaller, and slightly more for the larger, rockets; and also that the average velocity of the ejected gases is of the order of 1,000 ft./sec. It was found by experiment that a Coston ship rocket, lightened to 510 grams by the removal of the red fire, had a range of a quarter of a mile, the highest point of the trajectory being slightly under 490 feet. A range as large as this is rather remarkable in view of the surprisingly small efficiency of this rocket.

EXPERIMENTS IN AIR WITH SMALL STEEL CHAMBERS.

An apparatus was next constructed, with a view to increasing the efficiency, embodying three radical changes, namely, the use of smokeless powder, of much higher heat value than the black powder employed in ordinary rockets; the use of a strong steel chamber, to permit employment of high pressures and the use of a tapered nozzle, similar to a steam turbine nozzle, to make available the work of expansion.

Two sizes of chamber were used, one ½ inch diameter, and one 1 inch diameter. The inside and outside diameters of the smaller chamber Fig. 2 (a), were, respectively, 1.28 cm. and 3.63 cm. The nozzle, polished until very smooth, was of 8 degrees taper, and was adapted to permit the use of two extensions of different lengths. The length of the chamber, as the distance l in the figure will be called, could be altered by putting in or removing cylindrical tempered steel plugs of various lengths, held in place by the breech block.

Two small chambers were used, practically identical in all respects; one of soft tool steel, and one of best selected nickel steel gun barrel stock, treated to give 100,000 lbs. tensile strength. The charge of powder, P, was fired electrically, by a hot wire w.

Two dense smokeless powders were used: Du Pont pistol powder No. 3, a very rapid dense nitrocellulose powder, and "Infallible" shotgun powder, of the Hercules Powder Company. The heat values in all cases were found by bomb calorimeter.[1] All determinations were made in an atmosphere of carbon dioxide, in order to avoid any heat due to the oxygen of the air. The average heat values were the following:

Powder, in ordinary rocket......	545.0 calories/gm.
Powder, in Coston ship rocket....	528.3
Du Pont Pistol No. 3............	972.5
"Infallible"	1238.5

The ballistic pendulum used in determining the average velocity of ejection, for the small chambers, consisted essentoally of a plank, B, Fig. 3, carrying weights, and supporting the chamber, or gun C, in a horizontal position. This plank was supported by fine steel wires in such a manner that it remained horizontal during motion. In order to make certain that the plank actually was horizontal in all positions, a test was frequently made by mounting a small vertical mirror on the plank, with its plane perpendicular to the axis of the gun, and observing the image of a horizontal object—as a lead pencil—held several feet away while the pendulum was swinging. Current for firing the charge was lead through two drops of mercury to wires on the plank. A record of the

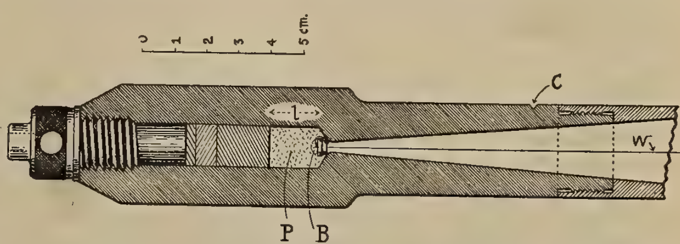


FIG. 2. THE SMALLER CHAMBER IN WHICH POWDERS WERE TESTED

displacements was made by a stylus consisting of a steel rod, S, pointed and hardened at the lower end. This rod slid freely in a vertical brass sleeve, attached to the under side of the plank, and made a mark upon a smoked glass strip, G. In this way the first backward and forward displacements of the pendulum were recorded, and the elimination of friction was thereby made possible.

*Abstracted from a paper by Dr. Robert H. Goddard, *Smithsonian Miscellaneous Collections*, Volume 71, No. 2.

[1]It was found necessary to use a sample exceeding a certain mass, as otherwise the heat value depended upon the mass of the sample.

The highest velocity was obtained with "Infallible" powder, and was over 7,000 ft./sec. The corresponding efficiency was close to 50 per cent. In view of the fact that this velocity is sevenfold greater than for an ordinary rocket, it is easily seen that the employment of a chamber and nozzle such as has just been described must make an enormous reduction in initial mass as compared with that necessary for an ordinary rocket.

As a matter of possible interest, photographs were taken at night of the flash which accompanied the explosions produced by firing the small chamber. Two of these are given in Figs. 4 and 5. Fig. 6 shows the set-up for these experiments; the camera being in the same position as when the flashes were photographed. The white marks, above the flash, are strips of cardboard, nailed to a long stick at intervals of 10 cm. and constituting a comparison scale, one end of which was directly above the "muzzle" of the gun. This scale was illuminated, before the charge was fired, by a small electric flash lamp held in front of each strip for a moment; which lamp also illuminated a card bearing the number of the experiment.

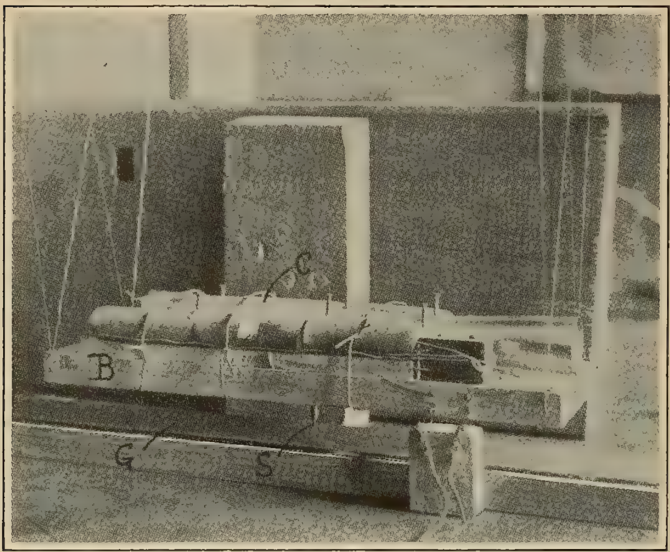


FIG. 3. BALLISTIC PENDULUM FOR DETERMINING AVERAGE VELOCITY OF EJECTION FOR THE SMALLER CHAMBERS

The photographs bring out a curious fact, *i. e.*, that the "flash" appears in most instances to be at a considerable distance in front of the nozzle. This is easily understood if we admit that the velocity of the ejected gases is very high just as the gases pass out of the nozzle, but becomes very quickly reduced nearly to zero by the air. In other words we may consider that the gases pass from the nozzle in an extremely short time—for too short to affect the photographic plate; and that it is only when the velocity has been considerably reduced that the "flash" is photographed.

In Fig. 5, a suggestion of this high-velocity portion of the flash is seen, which, it will be noticed, is less in diameter than the end of the nozzle. It should be remarked that it was only by accident that the nozzle was illuminated by the flashes in this experiment in such a way as to be seen in the photograph.

EXPERIMENTS WITH LARGE CHAMBER.

Inasmuch as all the steel chambers employed in the preceding experiments were of the same internal diameter (1.26 cm.), it was considered desirable that at least a few experiments should be performed with a larger chamber, first, in order to be certain that a large chamber is operative; and secondly, to see if such a chamber is not even more efficient than a small chamber. This latter is to be expected for the reason that heat and frictional losses should increase as the *square* of the linear dimensions of the chamber; and hence increase in a less proportion than the mass of powder that can be used with safety, which will vary as the *cube* of the linear dimensions.

The large chamber was of nickel-alloy steel 115,000 lbs. tensile strength. This chamber had inside diameter, and diameter of throat, both twice as large as those of the chambers previously used; but the thickness of wall of the chamber and the taper of the nozzle were, however, the same. The inside of the nozzle was well polished. Fig. 7 shows a section of the chamber; the outer boundary being indicated by dotted lines, *P* being the powder, and *W* the wadding. It will be noticed that the wadding is just twice the size of that previously used.

The mounting of the chamber, for the experiments, is shown in Fig. 9. The chamber was held in the lower end of a 3½-foot length of 2-inch pipe, *P*, by set-screws. Within this pipe, above the chamber, was fastened a length of 2-inch steel shafting, to increase the mass of the movable system. This system was supported by a half-inch steel pin, *E*.

On firing, the recoil lifted the above system vertically upward against gravity, the extent of this lift, or displacement, being recorded by a thin lead pencil, slidable in a brass sleeve set in the pipe at right angles to the pin *E*. The point of the pencil was pressed against a vertical cardboard, *C*, by the action of a small spring. This method of measuring the impulse of the expelled gases will be called the "direct-lift" method.

Although rebound of the gases from the ground would probably have been negligible, such rebound was eliminated by a short plank, *D*, covered with a piece of heavy sheet iron, and supported at an angle of 45° with the horizontal. This served to deflect the gases to one side.

In Experiment 51, with this large chamber, the Du Pont powder used was packed rather loosely. Any increase in internal diameter was inappreciable, certainly under 0.01 mm. In Experiment 52, the Infallible powder used was somewhat compressed. After firing, the chamber was found to be slightly bulged for a short distance around the middle of the powder chamber, the inside diameter being increased from 2.6 cm. to 2.7 cm., and the outside diameter from 5.08 cm. to 5.14 cm. The efficiency (64.53 per cent) in Experiment 51, and the velocity (7,987 ft./sec.) in Experiment 52 were, respectively, the highest obtained in any of the experiments.

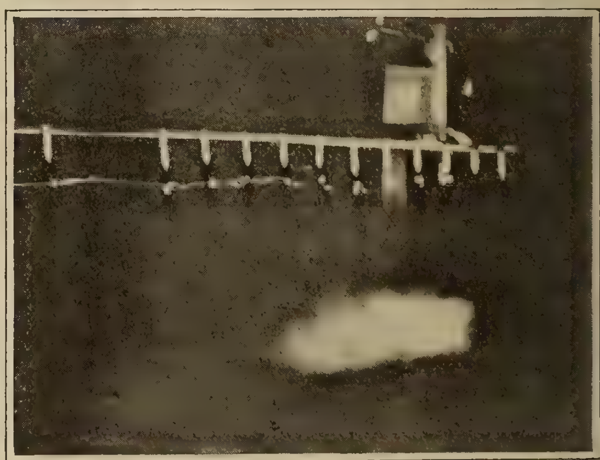


FIG. 4. PHOTOGRAPH OF FLASH FROM THE SMALL CHAMBER

The conclusions to be drawn from these two experiments are: First, that large chambers can be operated, under proper conditions, without involving undue pressures; and secondly, that large chambers, even with comparatively short nozzles, are more efficient and give higher velocities than small chambers.

It is obvious that large grains of powder should be used

in large chambers if dangerous pressures are to be avoided. The bulging in Experiment 52 is to be explained by the fact that the grains of powder were too small for a chamber of the size under consideration. It is possible, however, that pressures even as great as that developed in Experiment 52 could be employed in practice provided the chamber were of "built-up" construction. A similar result might possibly be had if several shots had been fired, of successively increasing amounts of powder. The result of this would have been a hardening of the wall of the chamber by stretching. Such a phenomenon was observed with the soft steel chamber already described, which was distended by the first few shots of Infallible powder, but thereafter remained unchanged with loads as great as those first used.[2]

EXPERIMENTS IN VACUO.

Having obtained average velocities of ejection up to nearly 8,000 ft./sec. in air, it remained to determine to what extent these represented reaction against the air in the nozzle, or immediately beyond. Although it might be supposed that the reaction due to the air is small, from the fact that the air in the nozzle and immediately beyond is of small mass, it is by no means self-evident that the reaction is zero. For example, when dynamite, lying on an iron plate, is exploded, the particles which constituted the dynamite are moved very rapidly upward, and the reaction to this motion bends the iron plate downward; but reaction of the said particles against the air as they move upward may also play an important rôle in bending the iron. The experiments now to be described were undertaken with the view of finding to what extent, if any, the "velocity in air" was a fictitious velocity. The experiments were performed with the smaller soft tool steel and nickel-steel chambers that have already been described.

METHOD OF SUPPORTING THE CHAMBER IN VACUO.

For the sake of convenience, the chamber, or gun, should evidently be mounted in a vertical position, so that the expelled gases are shot downward, and the chamber is moved upward by the reaction, either being lifted bodily, or suspended by a spring and set in vibration.

The whole suspended system was therefore designed to be contained in a 3-inch steel pipe, all the essential parts being

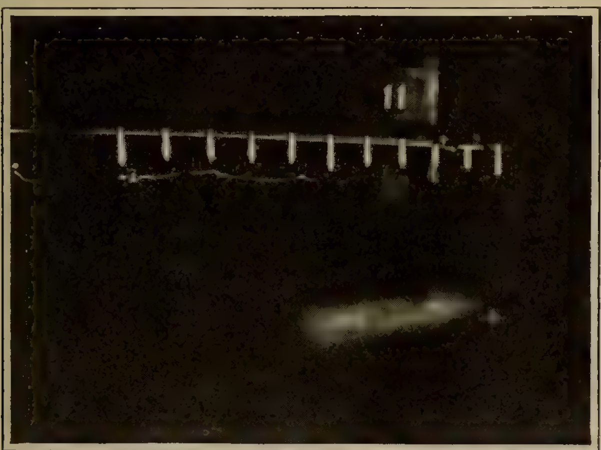


FIG. 5. ANOTHER PHOTOGRAPH OF FLASH. NOTE NOZZLE OF CHAMBER

fastened to a cap, fitting on top of this pipe. This was done not only for the sake of convenience in handling the heavy chamber, but also from the fact that the only joint that would have to be made air-tight for each shot would be at the 3-inch cap.

The means of supporting the chamber from the cap is shown in Figs. 8 and 10. Two 3/8-inch steel rods, R, R, were threaded tightly by taper (pipe) threads into the cap, C. These rods were joined by a yoke, at their lower ends, which served to keep them always parallel. Two collars, or holders, H and H', free to slide along the rods R, R, held the chamber or gun, by three screws in each holder. The inner ends of the screws of the lower holder were made conical, and these fitted into conical depressions, c, Fig. 2, drilled in the side of the gun, so that the lower holder could thus be rigidly

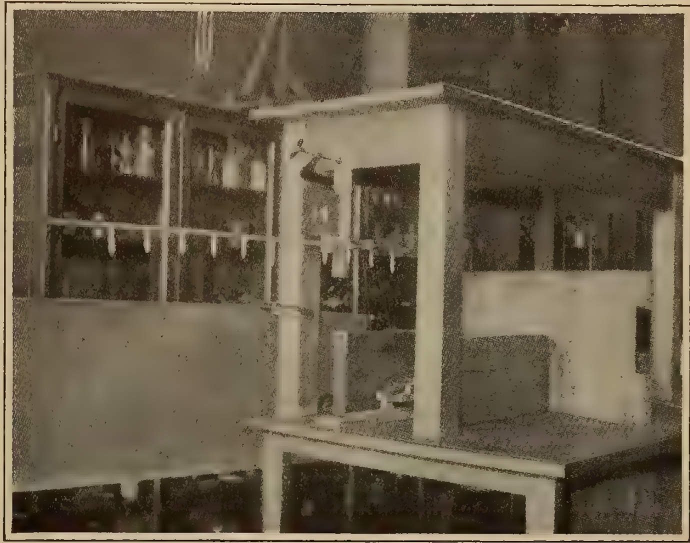


FIG. 6. SET-UP FOR EXPERIMENTS ON THE SMALL CHAMBER

attached to the gun. This was made necessary in order that lead sleeves, fitting the gun and resting upon the lower holder H', could be used to increase the mass of the suspended system. Three such sleeves were used, the two largest being molded around thin steel tubes which closely fitted the gun. The rods R, R, were lubricated with vaseline. Two ⅛-inch steel pins were driven through the rods R, R, just above the yoke Y, in order that the latter could not be driven off by the fall of the heavy chamber and weights when direct-lift was employed.

In the experiments in which the chamber and lead sleeves were suspended by a spring, the latter was hooked to its upper end to a screw-eye fixed in the cap C. The lower end of the spring was hooked through a small cylinder of fiber. A record of the displacements of the suspended system was made by a stylus, S, in the upper holder H. This stylus was kept pressed against a long narrow strip of smoked glass, G, by a spring of fine steel wire. This strip of smoked glass was held between two clamps, fastened to a rod, the upper end of which was secured to the cap C, and the lower end to the yoke, Y. Except for the largest charges used, it was possible to measure the displacements on both sides of the zero position, and thereby to calculate the decrement and eliminate friction.

When the chamber was suspended by a spring, a deflection as large as a centimeter was unavoidably produced merely by placing the cap C on the 3-inch pipe or removing it, although, in all cases the system would return to within one millimeter (usually much less than this) of the zero position after being displaced. In order to avoid any such displacement as that just mentioned, an eccentric clamp K, Fig. 10, was employed to keep the suspended system rigidly in its zero position during assembling and dismounting the apparatus.

This clamp consisted of an eccentric rod, K, free to turn in a hole in the cap C, the lower end being held in a bearing in the yoke Y. Through the upper end of this rod was pinned a small rod K', at right angles to K. The surface of the rod K was smeared with a mixture of bee's wax, resin, and Venice

[2]Since this manuscript was written, rockets with a single charge, constructed along the general lines here explained, have been considerably further developed.

turpentine; and the hole in the cap through which K projected was rendered air-tight by wax of the same composition.

The suspended system was assembled while the cap C was held by a support touching its under side. When the assembling was complete, the wax was heated by a small alcohol blow torch until it was soft, then a rubber band was slipped around the rod K' and the outlet pipe E. A trial showed that the cap could now be put in place on the pipe and re-

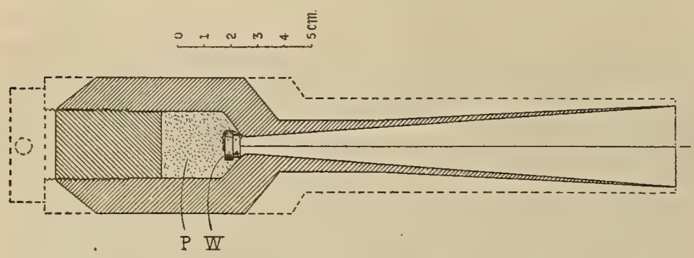


FIG. 7. SECTIONAL VIEW OF THE LARGE CHAMBER

moved, without moving the suspended system appreciably. After the cap C was in position on the pipe, the rubber band was removed, and the wax heated until the rod K could be turned out of engagement with the holders H, H'. After a shot had been fired, the clamp was again placed in operation until the system had been taken from the 3-inch pipe and the smoked glass removed.

The circuit which carried the electric current to ignite the charge consisted of the insulated wire W, which passed through a tapered plug of shellacked hard fiber, in the cap C, thence through a glass tube to the yoke Y, to which it was fastened. Below the yoke it was wrapped with insulating tape, except at the lower end where it was shaped to hold the 0.24 mm. steel wire, attached to the fine copper wire from the wadding. From the chamber the current passed up the rods R, R and out of the cap, around which was wrapped a heavy bare copper wire, V, which together with W, constituted the terminals of the circuit. It should be mentioned, in passing, that a small amount of black powder, B, Fig. 2 placed over the platinum fuse-wire on the wadding, was found necessary as a primer in order to ignite dense smokeless powders *in vacuo*.

In order to make the joint, between the cap and the pipe, air-tight during a determination, the following device was adopted. The outside of the cap, C, and also a lock nut, were both turned down to the same diameter. The lock nut was made fast to the pipe. These were then painted on the outside with melted wax consisting of equal parts bee's wax and resin with a little Venice turpentine.

When a determination was to be made, the cap was screwed into position, a wide rubber band was slipped over the junction between cap and lock nut, and the outside of this rubber band was heated with an alcohol blast torch. The result was a joint, for all practical purposes, absolutely air tight, which could, nevertheless, be dismounted at once after pulling off the rubber band.

THEORY OF THE EXPERIMENTS IN VACUO.

The expression for the velocity of the expelled gases are easily obtained for the two types of motion of the suspended system that were employed, namely, simple harmonic motion produced by a spring, and direct lift. Results obtained with simple harmonic motion (slightly damped, of course) were naturally more accurate than with direct lift, as it was impossible in the latter case to eliminate friction, but the former could not be used when the powder charges were large.

MEANS OF ELIMINATING GASEOUS REBOUND.

It should be remembered that the real object of the vacuum experiments is to ascertain what the reaction experienced by the chamber would be, if a given charge of powder were fired in the chamber many miles above the earth's surface. A container is therefore necessary, which, for the purpose at hand, approaches most nearly a container of unlimited capacity. A length of 3-inch pipe, closed at the ends, is evidently unsuitable, because the gas, fired from one end, is sure to rebound from the other end with considerable velocity, and hence to produce a much larger displacement than ought really to be observed. Moreover, any tank of fininte size must necessarily produce a finite amount of rebound, from the fact that the whole action is equivalent to liberating suddenly, in the tank, one or two liters of gas at atmospheric pressure.

There are two possible methods for reducing the velocity of the gas sufficiently to produce a negligible rebound: a *disintegration method*, whereby the stream is broken up into many small streams, sent in all directions (*i. e.*, virtually recon-

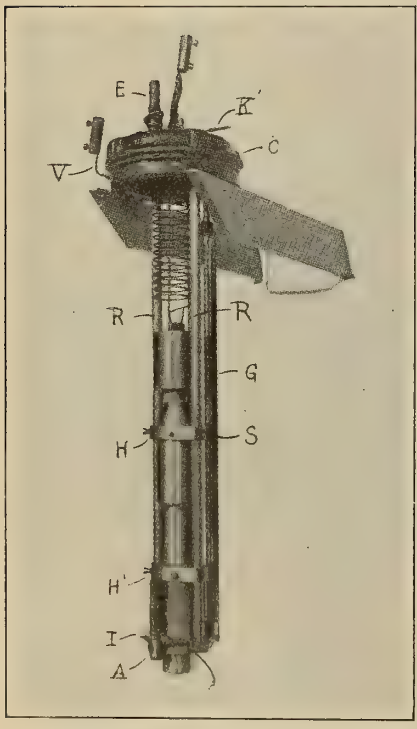


FIG. 8. MEANS OF SUPPORTING THE LARGE CHAMBER

FIG. 9. MOUNTING OF THE LARGE CHAMBER

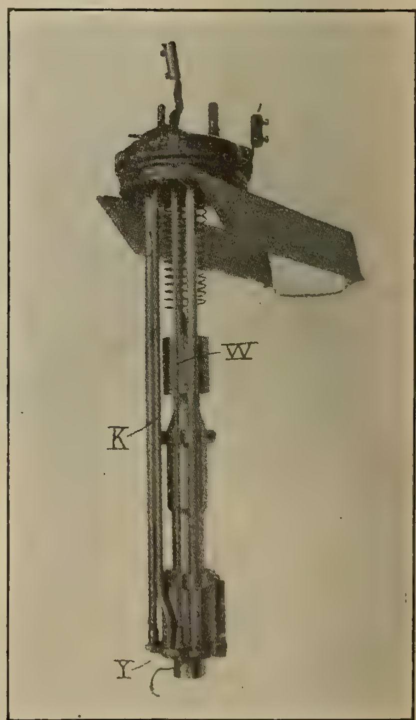


FIG. 10. VIEW OF THE LARGF CHAMBER SHOWING ECCENTRIC CLAMP K

verted into heat); and secondly, a *friction method*, whereby the individual stream remains moving in one direction, but is gradually slowed down by friction against a solid surface.

As will be shown below, accurate results were obtained by the first method, in what may be called the "cylindrical" tank; and these results were checked satisfactorily by the second method, in what will be called the "circular" tank.

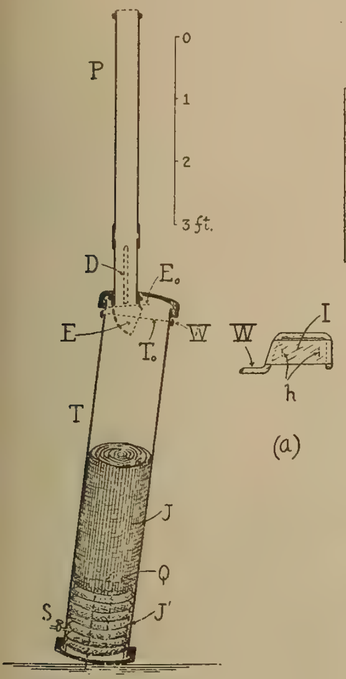


FIG. 11. THE CYLINDRICAL TANK.

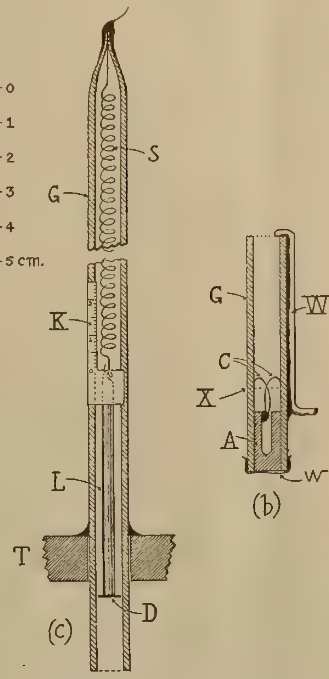


FIG. 12. THE TISSUE PAPER DETECTOR

The cylindrical tank was 10 feet 5 inches high and weighed about 500 lbs. It consisted of a 6-foot length T, Fig. 11, of 12-inch steel pipe, with threaded caps on the ends. Entering the upper cap at a slight angle was the 3-inch pipe P, 4½ feet long which supported the cap C of Fig. 8. The 12-inch pipe was sawn across at the dotted line T_0, so that any device could be placed in the interior of this tank, or removed from it, as desired. The upper section of the tank was lifted off as occasion demanded by a block and tackle. The two ends to be joined were first painted with the wax previously described; and after the tank had been assembled, the joint was painted on the outside with the same wax, W, and the entire tank thereafter painted with asphalt varnish.

This tank was used under three conditions:

1st. Tank empty, with the elbow E to direct the gas into a swirl such that the gas, while in motion, would not tend to return up the pipe P. In this case, some rebound was to be expected from this elbow. This expectation was realized in practice.

2d. Tank empty, and below cut off along the dotted line E_0. In this case, more rebound was to be expected than in Case 1, which was borne out in practice.

3d. Elbow E cut at E_0, and tank half filled with ½-inch square-mesh wire fencing. Two separate devices constructed of this wire fencing were used one above the other. The gas first passed through an Archimedes spiral, J, of 2-foot fencing, comprising eight turns, held apart by iron wires bound into the fencing. This construction allowed most of the gas to penetrate the spiral to a considerable distance before being disturbed, and of course, eliminated regular reflection. The second device, J', placed under the first, consisted of a number of 12-inch circular disks of the same fencing, bound to two quarter-inch iron rods, Q, by iron wires. These disks were spaced one inch apart. The three upper disks were single disks, the next lower two were double, with the strands extending in different directions, the next two were triple, and the lowest disk of all, two inches from the bottom of the tank, was composed of six individual disks. This lower device necessarily offered large resistance to the passage of the gas; yet strong rebound from any part of it was prevented by the spiral just described. With this third arrangement, small rebound was to be expected, which also was borne out in practice.

This tank was exhausted by way of a stopcock at its lower end, S; and air was also admitted through this same stopcock.

The circular tank, Fig. 13, was 10 feet high and weighed about 200 lbs. It consisted of a straight length of 3-inch pipe, carefully fitted, and welded autogenously, to a four-foot, 3-inch, U-pipe. The straight pipe entered the U-pipe on the inner side of the latter, and at as sharp an angle as possible. Another similar U-pipe was bolted to the first by flanges, with 1/16-inch sheet rubber packing between.

In this tank the gases were shot down the straight pipe, entered the upper U-pipe at a small angle, thus avoiding any considerable rebound, and thence passed around the circular part—not returning up the straight pipe until the velocity had been greatly reduced by friction.

In order to make the time, during which the velocity was being reduced, as long as possible, the pipes were carefully cleaned of scale. Care was taken to cut the hole in the rubber washers, between the flanges, so wide that compression by the flanges would not spread the rubber into the pipe, and thereby obstruct the flow of gas.

Notwithstanding all these precautions, evidence was had that the gases became stopped very rapidly. This was to be expected inasmuch as there is solid matter, namely, the wadding and wire, that is ejected with gas, which accumulates with each successive shot. This solid matter must offer considerable frictional resistance to motion along the U-pipe, and, since the mass of gas is only of the order of a gram, must necessarily act to stop the flow in a very short time.

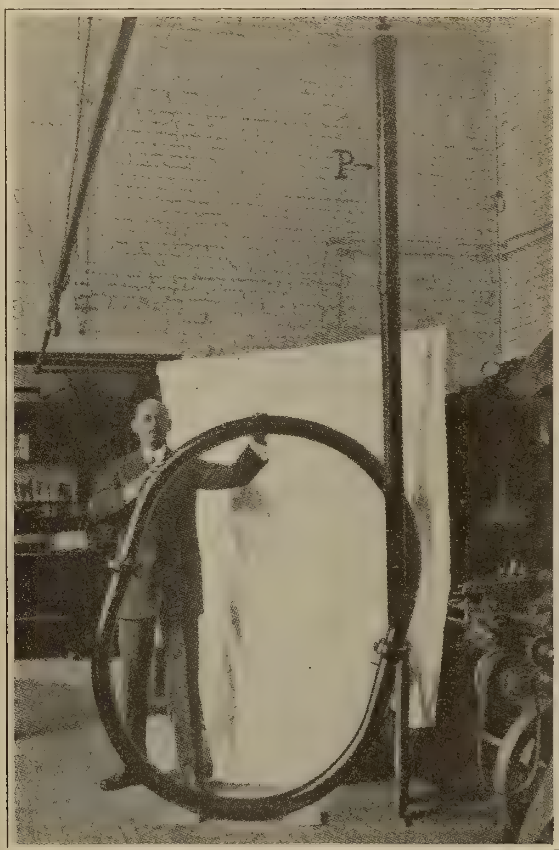


FIG. 13. THE CIRCULAR TANK

This interval of time was great enough, however, so that this second method afforded a satisfactory check upon the first method.

A possible modification of the above two methods would have been to provide some sort of trap-door arrangement

whereby the gases, after having been reduced in speed in a container as just described, would have been prevented from returning upward into the 3-inch pipe P by this trap, which would be sprung at the instant of firing. In this way gaseous rebound would be entirely eliminated. It was found, however, that results with the two methods already described could be checked sufficiently to make this modification unnecessary.

The tanks were exhausted by a rotary oil pump, supported by a water jet pump. In this way the pressure in the cylindrical tank could be reduced to 1.5 mm. of mercury in 25 minutes and to the same pressure in the circular tank, in 10 minutes. The pressures employed in the experiments ranged from 7.5 mm. to 0.5 mm.

METHODS OF DETECTING AND MEASURING GASEOUS REBOUND.

With the two tanks used in the experiments, it was obviously impossible to eliminate gaseous rebound entirely, from the fact that, even if the velocity of the gases is reduced to zero, there still remains the effect of introducing suddenly a certain quantity of gas into the tank. It became necessary, then, to devise some means of detecting, and, if possible, of measuring, the extent of the rebound.

Three devices were employed, one for detecting a *force* of rebound, and two for measuring the magnitude of the *impulse per unit area* produced by the rebounding gas. These latter devices, from the fact that quantitative measurements were possible with them, will be called "impulse-meters."

TISSUE PAPER DETECTOR.

The detector for indicating the force of the rebound consisted of a strip of delicate tissue-paper, I, Fig. 8 and Fig. 12 (a), 0.02 mm. thick, with its ends glued to an iron wire, W, as shown in Fig. 12 (a). This iron wire was fastened to the yoke Y, Fig. 10, and held the tissue paper, with its plane horizontal, between the chamber and the wall of the 3-inch pipe, P. In many of the experiments, the paper was cut 1/3 the way across in two places before being used, as shown by the dotted lines h in Fig. 12 (a). Since the tissue paper has very little mass, the tearing depends simply upon the magnitude of the force that is momentarily applied, and not upon the force times its duration—*i. e.*, the impulse of the force. The tissue paper will tear, then, if the force produced by the first upward rush of gas, past the chamber into the space in the 3-inch pipe above the chamber, exceeds a certain value. This first upward rush of gas will, of course, produce a greater force than any subsequent rush, as the gas is continually losing velocity. Even though the magnitude of the force that will just tear the tissue paper be not known, it may safely be assumed that if the first upward rush does not tear the paper, the force due to rebound that acts upon the gun must be small compared with the impulse produced by the explosion of the powder.

It should be noted that the tissue paper tells nothing as to whether or not there are a number of successive reflections or rebounds gradually decreasing in magnitude; neither does it give information concerning the *downward* pressure the gases exert upon the chamber tending to decrease the displacement, after they have accumulated in the space between the top of the chamber and the cap C, Fig. 8.

DIRECT-LIFT IMPULSE-METER.

A section of the direct-lift impulse-meter is shown in Fig. 12 (b). It is also shown in the photograph, Fig. 8, at A. A small cylinder A of aluminum of 1.46 grams mass, hollowed at one end for lightness, was turned down to slide easily in a glass tube G. This tube, G, was fastened by de Khotinsky cement to an iron wire W, which was in turn fastened to the yoke Y, Fig. 10, so that the glass tube, G, was held in a vertical position, between the chamber and the wall of the 3-inch pipe—similarly to the tissue paper. Two small wires C, C, of spring brass were cemented to the top of the aluminum cylinder, the free ends just touching on opposite sides of the glass tube. The inside of the glass tube was smoked with camphor smoke above the point marked X, so that a record was made of any upward displacement of the aluminum cylinder. The cylinder was prevented from dropping out of the glass tube by a fine steel wire, w, cemented to the tube and extending across the lower end.

There are two advantages of this form of impulse-meter. First, friction acts unavoidably to reduce the displacement. Secondly, any jar to which the apparatus is subjected on firing will cause the aluminum cylinder to jump, and thus give a spurious displacement. This latter fact rendered the meter useless for experiments in which direct lift of the chamber took place, as there was always much jar when the heavy chamber fell back, after being displaced upward.

This impulse-meter, it will be observed, gave a mean measurement of any successive up-and-down rushes of gas.

SPRING IMPULSE-METER.

A section of the spring impulse-meter is shown in Fig. 12 (c). The apparatus consisted of an aluminum disk, D, cemented to a lead rod, L, of combined mass 5.295 gms. supported by a fine brass spiral spring, S. The disk, D, was of a size sufficient to slide easily in a glass tube, G. The upper end of the spirng protruded through a small hole in the glass tube, and was fastened at this point by de Khotinsky cement, it thus being easy to make the top of the lead rod level with the zero of a paper scale, K, pasted to the outside of the glass tube. A piece of white paper placed behind the tube, G, made the motion of the lead roll L very clearly discernible.

This impulse-meter was placed in a hole in the upper cap of the 12-inch pipe of the cylindrical tank, at D, Fig. 11, and the same distance from the wall of the 12-inch pipe as the center of the 3-inch pipe. It projected one inch through the 12-inch cap which was practically the same as the distance the 3-inch pipe projected. The tube, G, was kept in position in the cap by being wrapped tightly with insulating tape, the joint being finally painted with the wax already described.

One important advantage of the spring impulse-meter over that employing direct lift is that the former has very little friction, so that the readings are very reliable. Another advantage is that the displacement of the former will include without any uncertainty the effect of any number of rebounds following one another in rapid succession—*i. e.*, the effect of multiple reflections of the gas, if such reflections are present.

In the vacuum experiments, the soft steel chamber was used for Du Pont powder, and the nickel steel chamber for Infallible powder.

The three nozzles were used, called short, medium, and long, and they were respectively 9.64, 15.88, and 22.08 cm. from the throat to the muzzle.

(*Here follows a table of experiments which for lack of space we have omitted.*—EDITOR.

DISCUSSION OF RESULTS.

1. There is a general tendency for the velocities *in vacuo* to be larger than those in air, for the same length of chamber, l, and the same mass of powder. For the medium nozzle, with Infallible powder, a comparison of experiments shows that the increase amounts to 22 per cent of the velocity in air.

2. The medium nozzle gives, in general, greater velocities than the short or the long nozzle with the same length of chamber, l, and approximately the same charges of powder.

3. The results show no appreciable dependence of the velocities upon the pressure in the tank between 7.5 mm. and 0.5 mm., and it is safe to conclude that the velocities are practically the same from atmospheric pressure down to zero pressure, except as regards the slight increase of velocity with decreasing pressure already mentioned.

4. A comparison of the results when the chamber moved under the influence of the spring with those in which the

chamber was merely lifted, show that the agreement of results obtained by the two methods is good, provided the displacement in the direct lift experiment is small. If, on the the other hand, the displacement in the direct lift experiment is *large*, this method gives considerably less velocities than the spring method. It is evident that *all the velocities obtained by experiments in which the lift exceeded 4 cm. are from* 300 *to* 600 *ft. sec. too small.* This is a very important conclusion, for it means that the highest velocities *in vacuo*, recorded in the table, are *doubtless considerably less than those which were actually attained.*

5. A comparison of the results obtained by means of the circular tank with those obtained by means of the cylindrical tank shows that the velocities range about 100 ft./sec. higher for the circular tank—a difference that is so small as to be well within the accidental variations of the experiments.

Concerning the behavior of the cylindrical tank under different conditions, a comparison of experiments shows that the velocities are much the same for all cases. Hence it is safe to conclude that the rebound, at least for small charges, is not excessive even if an empty tank is used, providing it is sufficiently large.

6. Concerning the proportion of the measured reaction that is due to gaseous rebound, the tissue paper detector, as has already been explained, does not give any information. All that this detector really shows is that the *force* exerted by the intial upward rush of gas past the chamber is not excessive.

The gaseous rebound could not be measured accurately with the direct-lift impulse-meter.

The spring impulse-meter used in the last five experiments gave reliable results because of the very slight friction during operation. This impulse-meter shows that, if the momentum of the chamber were to be corrected for gaseous rebound, *this correction would be much less than one per cent of the momentum of the chamber.* But as has been stated above, the impulse of the rebound at the chamber must be less than that at the impulse-meter, from the fact that gases may pass readily behind the chamber, and exert a downward pressure, and also because of friction in the 3-inch pipe. The effect of gaseous rebound is therefore negligible, and no account of it has been taken in calculating the velocities and efficiencies.

It now becomes possible to find, from the experimental results, the highest velocity *in vacuo* upon which dependence may be placed. This is evidently the result of Experiment 45 and is 2.34 km./sec. or 7,680 ft./sec. But Experiment 50 would have given without doubt, a velocity even higher, had friction properly been taken into account.

DISCUSSION OF POSSIBLE EXPLANATIONS.

1. The fact that the velocities are higher *in vacuo* than in air seems explicable only by there being conditions of ignition different *in vacuo* from those in air; although this may also have been due to the air in the nozzle interfering with the stream-lines of the gas, thus producing a jet not strictly unidirectional. It should be remarked that the highest velocity *in vacuo* recorded may have been due to unusually good circumstances of ignition; but may also have been due, in part, to being performed in the circular tank.

2. The fact that the medum nozzle gives in general velocities higher than the long nozzle shows that very likely after traveling the distance from the throat equal approximately to the length of the medium nozzle, the gas is moving so rapidly that it fails to expand fast enough to fill the cross-section of the nozzle. The efficiency could doubtless be increased by constructing the nozzle in the form of a straight portion, corresponding to a cone of 8° taper, for the length of the medium nozzle, with the section beyond this point in the form of a curve concave to the axis of the nozzle.

CONCLUSIONS FROM EXPERIMENTS.

1. The experiments in air and *in vacuo* prove what was suggested by the photographs of the flash in air, namely, that the phenomenon is really a jet of gas having an extremely high velocity, and is not merely an effect of reaction against the air.

2. The velocity attainable depends to a certain extent upon the manner of loading, upon the circumstances of ignition, and upon the form of the nozzle. Hence, in practice, care should be taken to design the cartridge and the nozzle for the density of air at which they are to be used, and to test them in an atmosphere of this particular density.

SIGNIFICANCE OF THE ABOVE EXPERIMENTS AS REGARDS CONSTRUCTING A PRACTICAL APPARATUS.

It will be well to dwell at some length upon the signficance of the above experiments. In the first place, the lifting power of both powders is remarkable. Experiment 51 shows, for example, that 42 lbs. can be raised 2 inches by the reaction from less than 0.018 lb. of powder. One interesting result is the very high efficiency of the apparatus considered as a heat engine. It exceeds, by a wide margin, the highest efficiency for a heat engine so far attained—the "net efficiency" or duty of the Diesel (internal combustion) engine being about 40 per cent, and that for the best reciprocating steam engine but 21 per cent.

It is, however, the velocity which is of the most interest. The highest velocity obtained in the present experiments is 13 ft./sec. under 8,000 ft./sec., thus exceeding a mile and a half per second (the "Parabolic velocity" at the surface of the moon), and also exceeding anything hitherto attained except with minute quantities of matter by means of electrical discharges in vacuum tubes. Inasmuch as the higher velocities range between seven and eightfold that of the Coston rocket we should expect a reduction of initial masses to be made possible by employment of the steel chamber, to at least the *seventh root* of the masses necessary for a chamber like the Coston rocket.

The supposition is, of course, that the mass of propellant material can be made so large in comparison with the mass of the steel chamber, that the latter is comparatively negligible. No attempt was made in the present experiments to reduce the chamber to its minimum weight. The minimum weight for the same thickness of wall as in the experiments, was calculated by estimating, first, the volume of a chamber from which all superfluous metal had been removed, and then calculating the mass of this reduced chamber, from the measured density of the steel.

It should be mentioned that, for any particular chamber, it will be necessary to determine the maximum possible powder charge to a nicety, from the fact that, as modern rifle practice has demonstrated, one charge of dense smokeless powder may be perfectly safe for any number of shots, whereas a slightly larger amount, or the same amount slightly more compressed will result in very dangerous pressures.

But the whole question of ratio of mass-of-powder-to-chamber is without doubt relatively unimportant for the following reason: The photograph of the flash, Fig. 5, in which the flash was accidentally reflected in the nozzle of the gun, shows the nozzle appearing stationary in the photograph, thus demonstrating that the duration of the flash is very small; but this, as already explained, is much longer than the time during which the gases are leaving the nozzle. The time of firing is, therefore, extremely short. This is to be expected, inasmuch as the high pressure in the chamber sets in motion only the small mass of gas and wadding, and hence must exist for a much shorter time than the pressure in a rifle or pistol. For this reason the heat such as is developed in the machine-gun, due to the hot gases remaining in the barrel for an appreciable time during each shot, as well as that due to the friction of the bullet, will be absent in the type of rapid-fire mechanism under discussion. Hence a large number of shots, equivalent to a mass of powder greatly exceeding that of the chamber, may be fired without serious heating.

Sources of Power Known and Unkown*

Vast Stores of Atomic Energy

By Sir Oliver Lodge, D.Sc., Sc.D., LL.D., F.R.S.

ALL that the human race can do in the material world is to move matter. To this end our muscles are designed, and only with their aid can we operate. Moreover, it is really through our muscles that we primarily enter into relation with the material world. Our muscular sense has informed us of the existence of an external world; it is that sense which enables us to interpret the indications of other senses, and which clearly discriminates "matter" from what might have been sensory illusion. All our physical activities may be summed up as the movement of matter; indeed, even our bodies are so composed, and are what we move in the first instance. The mind is in a different category, and when we think or will or remember, or suffer or enjoy, we are not necessarily moving matter; though usually some brain process accompanies these mental operations; but when a poet or a musician tries to express or record his thoughts, he has no other means available than to move a pen over paper, or work a violin bow or a keyboard, or of course he may set in action the muscles of his throat, and generate vibration in the air that way.

That the whole function of an engineer is to move matter is fairly obvious. Civil engineers, in a spirit of inverted pride, sometimes denote themselves as "dirt-shifters"; but the construction of a bridge, or of an engine, or of a dynamo, can also be described as the shifting and placing together of material objects. The farmer and gardener again, do nothing else. All real operations, from the production of electrical currents to the growth of seeds, are performed by Nature. Locomotion, in one form or another, is the business of man.

Every form of physical activity requires power; hence power or energy is the most pressing material need of man. Food and fuel obviously belong to the same class; for whether the power exerted be directly muscular or indirectly mechanical, makes no difference in principle. Yet there is a difference. Food is mainly used by an animal for developing energy before it has assumed the form of heat. Fuel, unfortunately, at the present time, has to produce heat first, so that the heat can be employed in some form of heat engine. We are thus up against the conception of temperature, and the inexorable law of efficiency, $\frac{T-T^1}{T}$. Heat can only be used when it falls in temperature from a hotter body to a cooler, and it is liable readily to fall in temperature without being utilized. When that happens there is loss of efficiency, and consequent waste of available power. A flagrant instance of fall of temperature with nothing to show for it, is the drop of temperature between furnace and boiler. All the heat may be transmitted through the walls of a perfect boiler, but it has become heat at a much lower level. The subsequent drop of temperature from boiler to condenser is utilized to the utmost by a multitude of ingenious devices from Newcomen and Watt down to Sir Charles Parsons, whose engines I suppose utilize this fall of temperature in the most direct possible manner. But if the temperature of combustion could be made use of, as in a frictionless flame turbine, more of the fuel energy could be utilized. Internal-combustion engines attempt this, no doubt successfully up to a point; but so long as they require cooling jackets, whereby heat falls in temperature without doing work, so long they are imperfect. Utilization of undesired local heat to generate high pressure steam, would seem likely to be a step in the right direction, and an engine with flame on one side of the piston and steam on the other has become known.

But animals do not turn their food energy into heat at all—save what is needed for warmth. Nor does a voltaic battery turn its chemical energy into heat. Any heat produced is waste: the chemical energy ought to go direct into an electric current; and an electric motor is capable of utilizing current energy very efficiently. Unfortunately, the chemicals are expensive, and it pays better to conduct electrochemical operations by aid of a dynamo and expenditure of mechanical energy, than to obtain mechanical energy from electrochemical operations.

It is important to realize that the law of efficiency $\frac{T-T^1}{T}$ is only applicable when the terms "heat" and "temperature" are applicable. The second law of thermodynamics refers to heat only, and not to any other form of energy. It does not apply to moving objects directly harnessed—like a fly-wheel; nor would it apply to molecules if their motion could be directly utilized. Organized and systematic motion is not "heat." In so far as the sun is a hot body, the formula is applicable, but it is a body at so excessive a temperature that the efficiency is nearly perfect. The fall of temperature from earth to absolute zero is 300°, but the fall from sun to earth is about 6,000°, hence the efficiency is $\frac{6000}{6300}$, or $\frac{20}{21}$, or very nearly unity. The leaves of trees, and vegetables generally, are able therefore to absorb and utilize solar energy in the refined chemical operations needed for the production of wood and coal, as well as of food, and they seem able to do this without much regard to any hampering law of efficiency.

This is undoubtedly the best way of utilizing present solar energy; and the moral is—promote agriculture of every kind, and in the widest sense. The solar rays which fall on the sea are not wasted; they are needed for wind and rain, and they give us all our water-power, but solar rays fallen on barren soil or hopeless jungle are a reflection on humanity: that kind of waste ought not to occur. The progress of bacteriological science might make every soil fertile; even rocks can be dynamited into something; and jungles and swamps should be cleared. We are not living in the carboniferous epoch, and we cannot wait millions of years for the contemporary production of coal.

But it is not food and fuel alone that we get from the present-day sunshine: We get wind and water-power, too; and it is economical to use them where we can. The beauty of a waterfall is enticing, but looked at with an engineering eye many waterfalls suggest a sad waste of power. And even when there is not a waterfall, so called, all water in descending from high-level lakes to the sea must be able to give out power which might be used wherever it is convenient to harness it.

In other ways the present sunshine may be utilized. I cannot regard with hope the idea of merely converting it into low-temperature boiler-heat. The barrenness of the Sahara would be the only excuse for the extensive use of burning-glasses or mirrors, and it is, perhaps, the only kind of place where such an enterprise could rationally be contemplated. But then there are very few parts of the Sahara where power is particularly wanted. Economy of transmission has a limit.

[A digression on the energy of the past sun may be permitted. All that the earth has caught, for all the millions of years that it has existed, is the merest fraction of what the sun has radiated in the same time. The earth to the sun is like a printer's full stop at a distance of ten feet from a halfpenny. Some of the radiation from a globe one inch in diameter falls on the spot $\frac{1}{100}$ in. in diameter ten feet away, but that little speck only catches the hundred and fifty millionth part of the whole. What has become of the rest of the solar energy? It must still be careering through space.

*Lecture delivered before the Royal Society of Arts, Dec. 10, 1919.

The ether is perfectly transparent, and only when it encounters matter will the radiation be mopped up and turned into heat. Not our sun only, but all the millions of other suns, have likewise been always pouring out radiation into space. Is there any hope of catching and utilizing it? I trow not. In spite of all this constant flood of energy, space is cold; very near absolute zero. The reservoir is so enormous that all these taps, running for ages, have made no impression on it, have not raised the level a perceptible amount.]

The only portion of the past solar energy available to us is that which was caught and stored by vegetation. This it is which has produced combustible matter; this it is, probably, which has also liberated free oxygen into the air.

The amount of atmospheric oxygen, and the amount of combustible matter in the earth's crust, were believed by Lord Kelvin to correspond; one was the chemical equivalent of the other; they had been separated by solar radiation. If so, the amount of combustible matter, of every vegetable kind, in the earth's crust can be estimated; for it is easy to estimate the amount of oxygen in the air.

The amount of combustible matter is limited, but the oxygen of the atmosphere is also limited. We have not exhausted the total fuel supply as yet, and it is to be hoped that we never shall attempt it. It would be poor progress if the human race, in pursuit of mechanical activity, were to burn up the air it breathes. There is plenty left at present, but no thanks to human beings or animals that it is so. All our factories burn it up. Only vegetation restores and renews it. We used to burn up the air of our rooms in order to light them; we do better than that now. The utilization of chemical or molecular energy seems necessarily limited. A great consumption of material yields comparatively little power. More plentiful and cleaner power is wanted. Some other source of energy ought to be discovered before the human race is a century older.

Are there any sources of energy not derived from the sun? Yes, two. The internal heat of the earth and the tides. Internal heat of some kind, whether due to radioactivity or otherwise, makes itself manifest in the neighborhood of hot springs and volcanoes. The eminent Italian engineer Signor Luiggi Luigi has shown us how to bore into the bowels of Vesuvius and extract from it some of its energy in a practical manner. A remarkably interesting achievement!

The utilization of the tides is continually being pressed by amateurs, but engineers rather take their stand with Lord Kelvin in recognizing the extreme slowness of tidal operation. They realize the vast reservoir that would have to be filled and emptied every twelve hours, and how likely it is that the reclaimed land of the reservoirs would be of more value than the power; at least in any locality where the power was really wanted, without prohibitive distance of transmission.

The power of waves is different. That does come from the sun, and it is not leisurely like the tides. Those who have watched Atlantic rollers booming into creeks on the west coast of Ireland have felt that here surely was available power. We may imagine a dreadnought (now let us hope of no further use) attached by a long girder to rack-work machinery, and being hoisted up and down by the waves. The weight that could thus be hoisted might be far greater than a dreadnought—the whole German fleet for instance might be attached to the lever; it would give a good many foot-tons per minute; but whether any machinery would stand the strain I do not know. The idea is probably absurd, but it seems to me less problematical than the tides. Besides, in large harbors the tides are wanted for scouring purposes, and for clearing away a bar.

Is there any concealed store of energy recently discovered and not yet utilized? There is indeed. There are two,—one certain, the other rather hypothetical: the energy of the Atom, and the energy of the Ether. I propose to say nothing about etheric energy. If it exists, as I think it does, it is enormous, exceeding the bounds of imagination; but at present it is utterly beyond our reach. Atomic energy is rather inaccessible too, but not hopelessly so. It is far less in amount than etherial energy, but it is immense compared with any form of chemical or molecular energy, such as that derived from combustion or explosives.

By atomic energy I mean the constitutional energy of an atom—the energy which makes it what it is. If this energy is given up in any considerable degree, the substance ceases to be what it was, and becomes a substance lower down in the scale. Utilization of atomic energy would involve the stepping down, the degradation, of matter. The term is purely technical—it has been already applied to energy without moral stigma. All it means is that heavy atoms may become lighter atoms, and in so doing must give off a definite proportion of their great store of energy.

This spontaneously happens in the phenomenon known as radio-activity. If it had not spontaneously happened, we should have known nothing about the energy concealed in an atom. The explosive or radio-active atom has given the secret away. All atoms possess energy, but some cannot hold it all. These are the radio-active elements, and they periodically fire off projectiles with more than volcanic violence. A radium atom firing off a particle, which turns out to be a postively charged atom of helium, is like a two-ton gun firing a hundred-pound shot. That is about the actual proportion between the projectile and the rest of the atom; which naturally recoils each time it fires. The recoil has been observed. Before it has exhausted its ammunition it fires off five such projectiles, and then settles down into a quieter existence as lead—or, if not exactly lead, something chemically indistinguishable from lead. A uranium atom had already fired off four projectiles in order to become radium. Radium is a temporary half-way house between uranium and lead: it is active, but not so fiercely active as some of the intermediate substances, which last so short a time that they barely have names. They destroy themselves by their own activity, and consequently are very scarce—like a population with a high death-rate. Radium is of moderate activity; its lifetime is of the order of a thousand years, whereas the lifetime of some of the intermediate substances may be measured in weeks or even minutes. Yet they are real elements, with a place in the series, and they have definite spectra and chemical properties.

Do not suppose that the well-known radium is an exceptional substance. It would seem that all substances of very high atomic weight are liable to behave in this way—it is only a question of degree. And it is not by any means their whole energy that they thus exhibit, it is the energy they expend and get rid of—their waste energy—which we perceive. And when we speak of their explosion, it is to be noted that the explosion is not a shattering or bursting of the gun, it is merely the firing of a shot; except that in the atomic case the shot was part of the gun. The energy retained is far more than the energy expended. And when its active transformations have ceased and left it in a stable state, like lead or gold or silver or copper or iron, or any common element, we are not to suppose that because it is quiescent therefore it has no store of internal energy. Appearances are deceptive. Anyone looking at cordite might think it harmless enough; and so it is till a suitable stimulus is applied. It does not go off spontaneously, or at least it is not wanted to. Gunpowder and any other explosive exhibits no trace of its secret to mere inspection; nor do the atoms of ordinary matter show that they are fearfully energetic; but the energy is there.

We may now go on to ask: What corresponds to the gunpowder, when I speak of a gun firing a shot? What propels the projectile? It is a very proper question, but at present it can only be partially answered.

There are two kinds of projectiles fired off by a substance—

the heavy shot or α ray, which is known to be a helium atom, and the lighter shot or β ray, which is the fundamental unit of electricity, the negatively charged unit particle—an electron. Several electrons may be expelled, and they will not make much difference to the weight of substance left behind, but they will have left it positively charged; and in that case it is liable to fling away one of its massive positively charged particles, too. One event follows the other, and whether the electron always escapes first is uncertain. Whichever event precedes, in different cases, the other is likely to follow.

Many circumstances can stimulate the escape of an electron; not, in deed, of the deeper-seated constitutional electrons, but of the outlying superficial charges which are responsible for chemical affinity. Mere friction removes some of them, and leaves the substance positively charged. The removed electrons will have gone to the rubbing substance, and will have charged it negatively. Splashing of water, chemical action in innumerable forms, effects the transfer of electrons, and consequent charging of bodies. Ultra-violet light falling upon clear metal, and indeed upon a large variety of substances, causes electrons to be expelled, until the surface is positively charged enough to hold them back. The discharge will go on continuously if more are supplied from a battery. The jostling of the molecules by heat will often cause electrons to escape, but not usually until a temperature of red or white heat is reached. Singularly enough, a comparatively low temperature will emit a few positive particles for a time; but this emanation soon ceases, the material gets tired as it were, and has to be re-born or renewed somehow, if the process is to be continued. Not so with the negative emission from hot bodies. This will go on as long as fresh particles are supplied.

In many ways, therefore, we can stimulate the escape of stray electrons, and it appears that by the aid of X-rays, or of projectiles from other atoms, we are beginning to learn how to disturb effectually, and even to eject, the deep-seated constitutional variety; though usually others immediately take the place of the ejected one, with consequent radiation of definite type. If a pair of β particles were permanently extruded, an α ray would probably follow, in order to restore the neutrality of the atom; and the atom would have gone a step down in the scale. This happens spontaneously, but the result of experience is that we cannot bring about the catastrophe by ordinary means. We cannot alter the spontaneous rate, by anything we as yet know how to do. Heating and cooling alterations of molecular movement—seem impotent to get down to the inner mechanism. Still, we are certain that inner mechanism is a most energetic system; and just as the internal charges are equally positive and negative, so I believe atomic energy is both static and kinetic—though perhaps not equally so.

The modern view of an atom is a central positive nucleus like a sun, and a revolving system of negative electrons like planets. The electric planetoids, so near this "sun," and subject to its powerful electrical attraction, must be revolving with prodigious speed, and with a frequency of orbital revolution exceeding in most instances even the frequency of light—a frequency only attained in general by the ultra rapid X-rays. Accordingly, these little bodies have plenty of kinetic energy, and when they escape as β rays, they do so with something like the velocity of light.

The *frequencies* possible in a hydrogen atom turn out, in Bohr's theory, to be of the order 10^{16}, being either 10^{16} itself or else $\frac{1}{8}$ of 10^{16}, or 1/27 of 10^{16}, the denominators being the natural cubes. For heavier kinds of atoms, this frequency must be multiplied by the square of the number allotted to the element in Mendelejeff's series.

The *diameters* of the orbits will be of the order 10^{-8} cm. divided by the atomic number and multiplied by the successive square numbers, 1, 4, 9, etc.

The *velocities* will be of the order 10^{8} cm. per second multiplied by the atomic number and divided by the natural numbers, 1, 2, 3, etc.

So for the heavy atoms, whose atomic number is approaching a century, the inner electron speeds are getting near to the velocity of light; hence probably their instability.

The positively charged nucleus is in different case. Its energy is more likely to be static, *i. e.* potential, like things held or caught together, as a detent may hold a strong spring. Let them be liberated, and they fly with great violence, presumably under electrical repulsion; the potential gradient near the nucleus is enormous, and the speed therefore very great, so that each atom where it strikes a zinc sulphide target makes a luminous splash. Taking the size of the nucleus as comparable to 10^{-12} cm., the acceleration of an α particle is Ne^2/Kmr^2, m being the mass of a helium atom; and this equals $3 \times 10^{28}N$ centimeters per second, at the start, and must be reduced to near zero at the confines of the atom. (N is the atomic number.)

The projection of an α particle is therefore literally an explosion, and the force can very quickly get up an enormous speed. (The acceleration of a bullet in a rifle is comparative to 10^7 or 10^8 of the same units, at most.) The speed with which an α particle is ejected is about one-fifteenth that of light—sufficient to carry it to New York, if there were no obstruction, in a quarter of a second. Its energy is therefore, weight for weight, a million times that of a bullet. Only because an atom is so small does it fail to do any damage.

But the number of projectiles from a milligramme of radium is about thirty million a second; hence, in the aggregate, they generate a very perceptible amount of heat. We may not know the exact cause of their retention, or of their propulsion, but no one can deny that the energy is there. The main difficulty is to understand how they are retained and packed together into the exceedingly minute nucleus. The natural suggestion is that the cement consists of interleaved or interlocked negative electrons; and when these are dislodged by some perturbation from the orbital part of the atom, or by the impact of a projectile, the liberated positive particles are driven asunder.

As to the atoms' orbital electron energy, that is probably kinetic, they probably escape with the velocity with which they were revolving in their orbits before perturbation. This is rendered plausible by the fact that their emission depends on synchronism between the periods of the particles and the X-ray disturbance which ejects them. Their energy of ejection is found to depend on the frequency of the radiation which stimulates it; a fact which at once suggests a storing of received synchronous vibrations, till a quantum of energy sufficient for ejection has been accumulated. Moreover, spectrum analysis of the derived or secondary X-rays, emitted by a substance exposed to radio-active bombardment, is also a test of the frequency of orbital revolution.

Particles can be ejected from one of several orbits—called respectively K or L or M, the K orbit being the nearest to the nucleus and therefore of highest frequency. Electrons are ejected at speeds still greater than α particles, and occasionally approach to within a few per cent of the speed of light.

If we calculate the amount of energy thus quietly existing in the atoms of any visible piece of matter, we shall find it enormous. If each atom is the seat of these high velocities, and equivalent high explosive forces, the aggregate of energy in a few trillion atoms is very great; and it takes fully a trillion atoms to make a perceptible speck of matter.

To illustrate the energy possible in any reasonably small quantity of substance, it is sufficient to reckon the energy in a couple of grammes, or say thirty grains, of matter moving at one-tenth the speed of light. It need not be moving in the sense of locomotion; internal motion of its parts does just as well; and static energy can be equally well included, since its liberation will produce these high velocities. The energy is 10^{19} cgs. units or ergs. Now a foot-ton is 3×10^{10} ergs.

Hence the energy of a few grammes of matter is three hundred million foot-tons, enough to raise a hundred thousand tons 3,000 feet. If all its parts were moving with the speed of light, the energy would be a hundred times greater, but it is doubtful whether bodies can move at quite the speed of light. For, just as a bullet cannot move quicker than a thermally modified velocity of sound, so a body is unlikely to move through the ether quicker than the ether disturbance can get out of the way.

No doubt a large store of energy is there; the practical question is, can we get at it and utilize it? We may even ask: Is any of it being utilized already? I do not think the answer is wholly in the negative; for that the activity of radium, theorium, and other radio-active substances, is employed therapeutically is well known. That was the beginning of practical application of the energy given off.

Atomic energy may unconsciously be being utilized in other ways, too. I have lately put forward an incipient radio-active theory of vision: I surmise that in the retina there must be a substance which can be stimulated into activity by the impact of ether waves of luminous frequency, that the substance then ejects a few of its outlying electrons, and that these stimulate the nerve-endings in their immediate neighborhood. The way in which air vibrations stimulate the auditory nerve has been fairly made out; it is a question of mechanism; but the way an etherial vibration stimulates the optic nerve has not been made out: it is not a mechanical, but an electrical question. Radiation of high frequency is known to be received and stored until it is able to eject a negative particle with whose orbital frequency it happens to agree. And certainly such a particle when ejected could be depended on to stimulate a suitable nerve ending.

It is on those lines that I would explain the extraordinary sensitiveness of the eye. For the accumulation of a few million impulses would take no appreciable time, and it is difficult to suppose that in any other way than by synchronisation with some equally rapid intrinsic motion, could matter be perturbed by the extraordinarily rapid vibrations of ether—hundreds of millions of millions per second. Nothing larger than the ultimate elements of the atom could be expected to follow such rapidity. Molecules of matter would be almost too massive and gross to be readily moved as a whole; and, besides, their movement as a whole would only result in heat.

The same sort of idea could apply to the stimulus of a sensitive photographic plate; only here the chemical atoms are attuned, as a rule, to still higher rates of vibration, and are susceptible beyond the ultra violet, into the region of X and λ rays.

The facts of color vision suggest that the visual substance (visual purple, or whatever it is) is specially sensitive to three particular frequencies, one in the red, one in the green, and one in the violet; but there must be plentiful overlapping, so that intermediate wave lengths may produce their full effect.

The whole idea at present is in the nascent stage: only it is instructive to think that possibly atomic energy may have been utilized in the eyes of animals all the time. It is conceivable that it may have been utilized for the light emission of glow-worms, though that is generally and perhaps rightly considered to be due to molecular or chemical energy. Atomic energy is not chemical at all, but physical—at least, when the constitutional and not the outlying electrons are in question. It is possible that the absorption of solar energy by chlorophyll in plants may also in some way utilize atomic energy, stimulated into catastrophic activity by light waves. These things are only possibilities, which observers and experimenters may do well to follow up, and, if need be, negative.

But of late an application of atomic properties *in vacuo* has undoubtedly been made. Ordinary electric valves depend upon the different behavior of positive and negative particles; and an electric bulb containing a positive electrode and a hot wire cathode was employed, some years ago, as a receiver for wireless telegraphy, by Professor J. A. Fleming. When the hot wire or filament is negatively charged, a stream of electrons reach the anode. When it is positively charged, the emission is checked. So if an alternating current is received, the emission of electrons is alternatively helped and hindered, and thus the current is rectified and made capable of being received by any ordinary instrument. The cutting up into signals has to be otherwise managed, for the alternations are too quick to be acoustically perceived.

Then Lee de Forrest introduced an improvement, and made it not only a wireless receiver but a relay or amplifier. Between negative filament and positive anode, in an exceptionally high vacuum, he placed a perforated grid or coiled wire, with interstices that would let the electrons through; and instead of applying the received alternating pulses to the anode, he applied them to the grid, placed above or facing the red-hot cathode, with the anode above or behind the grid. The effect on the escaping charged particles was the same,—the stream of current-carrying particles was helped or hindered, encouraged or stopped, as before; but now a strong battery could be applied between anode and cathode, and some mechanical receiving instrument, telephone or what not, could be placed in the auxiliary or relay circuit. Weak impulses applied to the grid, according to their positive or negative sign, will now serve to control the stronger current in the auxiliary circuit; and so a received message that in itself would be hardly audible can be magnified a hundred-fold.

Electrons emitted by a hot wire are not flung off with any prodigious speed; they seem rather to evaporate off at a red or white heat, and their subsequent course is controlled by the gradient of electrical potential in which they find themselves. The force acting on them is $F = e dV/dx$, and the total work done is $F dx = e V$; that is to say, the energy generated depends simply on the total drop of voltage through which they pass. Their speed is given by

$$\tfrac{1}{2}mv^2 = e\ (V - V^1),$$

and it is usually considered sufficient to specify the voltage through which they drop, as adequately representing their externally generated speed.

They come off with *some* velocity, however; call it u; but a small opposition voltage will suffice to quench this, as gravity quenches the speed of a cricket ball thrown vertically up, and sends it down again. So it is with the electrons from a hot wire. Any potential difference greater than $mu^2/2e$ will return it whence it came. One volt rise in potential would be able to quench a speed of 450 km. per second.

That, then, is what happens between grid and hot wire. If the grid potential is negative, and greater numerically than the minimum value, the stream of electrons from the hot wire is stopped and sent back; if the grid is positive, the speed upward of the lectrons is encouraged. They shoot through the pores of the grid, they reach the anode above it, they establish connection and convey the current. The auxiliary circuit, between anode and hot wire, is completed by them, and the signal is given. But this only happens when the grid allows of their passage. If the potential of the grid is adverse they never pass through it at all, but just return depressed to the hot wire. Electric evaporation is checked, just as the evaporation of water is checked in a closed space, not because no particles spring out, but because an equal number are returned. A positive grid promotes evaporation, a negative grid checks it, an alternating grid causes an alternating stream to pass through it; and the electric stream can follow every minutest fluctuation; for electron inertia is as nothing, and they respond instantly to the slightest force.

To get quickness of response the projectiles must not be allowed to bombard other molecules, so as to ionize them and render the whole atmosphere conducting. For this ionisation would not subside instantaneously, and therefore the current would not be completely under control. To avoid ionisation by impact, the reservoir must be very highly exhausted; the cur-

rent ought to depend on the projectiles themselves, not on their secondary and adventitious effects.

It is to be noticed that the kind of electric emission from a hot wire differs greatly from that stimulated by ultra-violet light or X-rays. These vibratory agents dig right down into the constitution of the atom, and eject electrons whose orbital frequency agrees with their own. The "harder" the ray, that is, the higher the frequency of the impinging radiation, the higher the velocity of the ejected electron—evidently because one of the innermost orbits is then perturbed. For in inner orbits the speed must be high, in accordance with Kepler's third law. The orbital speed varies inversely with the square root of the radius of the orbit. And the more massive the nucleus the greater the speed necessary to balance the centripetal force.

But the jostling of atoms by heat produces no such deep-seated effects. The effect of heat in a metal is as if a kind of atmosphere or crowd of stray electrons evaporated and escaped. It is unlikely that the electrons in a metal are really loose, but some of them are so slightly attached as to be practically loose—readily passed from atom to atom in the process of conduction, and readily expelled under the irregular impulses of heat.

Whether heat is the best way of promoting this electronic emission may be doubted. It seems an extravagant method, analogous to employing an electro-magnet where a permanent magnet would do, or to supporting a roof by a jet of water. But the other kind of stimuli, such as those promoted by radioactivity or ultra-violet light, do not seem to generate the right kind of docile emission. The very high-speed electrons would require too much potential to hold them down. The speed of electrons ejected by X or λ rays is definite, and depends on the frequency of the rays; but the speed of emission of electrons from a hot body is indefinite and irregular, being distributed in accordance with Maxwell's law for a monatomic gas. Moreover, the escape through the skin of a metal is equivalent to an escape against a "contact" difference of potential; and thus, in some cases, the electrons may be said to ooze rather than to fly out, and to owe their subsequent speed entirely to the external potential gradient in which they find themselves.

That state of things would be quite convenient for wireless telegraphy, since they would then be still more readily under control. The skin retardation exerted by tungsten has been measured as 4.6 volts, unless I am mistaken.

To return to practical applications of these atomic properties—for it is atomic properties rather than atomic energy that is at present being utilized. Not only is it possible to employ a relay in the way described, for the emission and receipt of wireless waves, but one relay can be used to stimulate another; and this can be done several times in succession, and immense magnification attained; for the electric stream is so rapidly responsive and docile that it can follow fluctuations that no mechanical relay could possibly follow. The rapidity of signalling thus rendered possible in the Morse Code is surprising. Of course an automatic sender, and some form of chemical or quick-responding receiver, must be used; and then the message can be as rapid as one can speak. The words are spelt out, without abbreviation, in dots and dashes; and yet the words come on to the tape at three hundred a minute, five a second or thereabouts.

It is also becoming well-known that Morse signals need not be used, but that ordinary speech itself can be thus wirelessly but electrically transmitted, with quite good clearness of articulation. Every auditory frequency is slow compared with what the atomic projectiles can follow, hence every variety of speech-sounds, vowels and consonants, can be readily picked up and transmitted into electric fluctuations. This is done at the sending end, and the aerial accordingly emits waves, which, though they have their own electric rate of vibration, succeed one another in batches corresponding to the acoustic frequencies. At the receiving end the succession of waves are picked up by the aerial there, and once more converted back into telephonic speech through the medium of one or more valve relays and appropriate devices.

There are many details, and great ingenuity has been expended in bringing this method of wireless telephony to the perfection which it has thus far attained. The whole thing is most hopeful, and splendid work is being done at wireless research stations. (I have recently seen the Government one at Woolwich, under Colonel Cusins and a devoted staff of workers, and have gone over it with great admiration.)

The interest to us, here and now, is that it is by the harnessing and practical utilization of purely atomic properties, that all this great advance in practical electrical engineering has been accomplished. The conclusion is inevitable that much more remains to be done.

A NEW PROCESS FOR PLATING ARTIFICIAL STONE WITH METAL.

THE varieties and applications of artificial stone have become increasingly manifold in the present century. In 1901 an Austrian inventor, Lundwig Hatschek, took out a patent for a new kind of artificial stone, having as its chief elements asbestos and cement. Tiles of this substance called Eternit and Zenit have been extensively used for building purposes especially for roofing. However, such tiles are not absolutely impervious to water and to frost. Many attempts, therefore have been made to improve the material by painting or covering with metal. For example, in one process the tiles were painted with copper and aluminum bronze and then polished but this application was found to be not very durable. Another attempt was made to cover the stone with a metal coating by means of the Schoop spraying porcess, but since no intimate connection is thus formed between the metal crust and the mass of the artificial stone, the metal peels off in the course of time.

The problem has now been successfully solved, according to the *Elektrochemische Zeitschrift* (Berlin) by an engineer named Henry Welte, after several years of study and experiments. His process, which is patented (DRP. 288,435) furnishes asbestos-cement roofing tiles with a metal overlay which renders them absolutely watertight and resistant to frost. Furthermore, the metal covering clings solidly to the plates of stone. These virtues have been certified to by the Experimental Station of the Technological Trade Museum in Vienna, and the Chemical Laboratory of the Clay Industry in Berlin.

The process of manufacture is exceedingly simple and can be incorporated without trouble in the scheme of any artificial stone works. Before the shaped articles are placed under the hydraulic press the entire surface is covered with powdered metal, which is sifted on so as to form a thin coating. The single particles of the metal powder are given either a spherical or an irregular form, as the case may be. The object is then placed under the press and the pressure causes the upper surface of the particles of metal to be flattened and to unite with each other, forming a uniform layer. This coating is compactly united with the mass of stone by means of the pressure, the cement being forced into the interstices of the particles of metal beneath but without being extruded through the upper surface.

All sorts of objects, tiles, building stones, pipes, etc., can thus be covered with any desired metal. Another advantage which is of great importance is that plates thus covered can be welded together, thus greatly simplifying the making of a water tight and frost tight roof, the upper surface of the stone being covered with lead or copper, or with a lead coating which has been copper plated by the galvanic method. The process also lends itself to decorative purposes, since it can be applied to objects such as bath tubs, bath rooms, washstands, ice boxes, electric fixtures, etc., decorated in relief. This new invention will also be of great value in the construction of chemical appliances because of the resistance to acids attained by the use of the proper metal overlay.

The Apparent Form of the Sky*

A Penultimate Word on This Much Discussed Subject

By Camille Flammarion

The following article is a report of a lecture by M. Flammarion. While the distinguished astronomer here sets forth his views in answer to those expressed in a previous lecture by Dr. Dubief, his address is in no way dependent upon the former for comprehension, both text and illustrations being self-explanatory.—Editor.

If I give to this informal address the title of a *penultimate word* on the apparent form of the heavens, it is because I feel that the ultimate word will never be spoken, and that at any rate I myself should never venture to utter it. The learned and picturesque lecture with which Dr. Dubief has charmed us, has shown, by the new light which he has shed on this ancient question, how complex the subject is and to what varied discussions it can give rise.

It is indeed an ancient question. Yesterday I ran over the titles of 250 memoirs specially devoted to this subject in the course of more than a thousand years. As a curiosity I will set before you one of the oldest dissertations, that of the Arab Alhazen, a tenth century astronomer, whose treatise on optics, translated into Latin in 1270, was published in 1572 under the somewhat heavy form here exhibited. It is a bibliographical curiosity. We might read, had we time, among these demonstrations of refraction, chapters 51 to 55, upon the aggrandizement in size of stars upon the horizon. But I spare you; chapter 55 contains no less than 146 lines of this gigantic format in a single paragraph and in not very classic Latin. You see, Gentlemen, that our ancestors were as laborious as we. Alhazen's opinion was that the vapors of the air were the principal cause of the enlargement of stars upon the horizon. This is still the opinion today of my illustrious friend Camille Saint-Saëns, with regard to which I have been doing battle with him since the days of Samson and Delilah. I have neither the strength of Samson to pull down the walls of a Cyclopean temple, nor the charm of Delilah to dazzle the eye, but I venture to believe that the mere naked truth will suffice to assure the victory.

After Alhazen, as a serious authority, we may cite Kepler. I owe it to the erudition of our colleague, M. Gaston Havet, that my attention has been called to his *Epitome*, which contains the following lines on p. 82 of the edition of 1618:

"Jam vero cum constellationes versantur in coeli medio, corpus aeris nec profundum est, respectu aspectabilis latitudinis terrarum, nec profundum esset, conspici potest ijitur ex absentia corporum interjectorum: ratiocinatur sensus communis per errorem,sidera cum sunt in coeli medio, nobis esse propinquiora, quam cum oriuntur et occident: tunc enim censentur remotiora, quia valles et montes inter nos et orientia sidera longissimo tractu interjecti, patent oculis. Sequitur ijitur error alter, ut sol, qui manet ejusdem magnitudinis, aestimetur culminare parvus admodum, oriri vero ingeus, ut gigas.

"Eorum enim quae videntur eodem angulo visionis, illa sunt majora, quae remotiora, ut docemur in opticis."

This is the explanation which has always seemed sufficient to me: that of the aspect of sky, which seems nearer to us above our heads than at the horizon, as was later set forth by Malebranche and Robert Smyth. At our session of March 5, 1913, devoted partially to this subject, I said, repeating what I had already published in 1872 in the first edition of my work, *L'Atmospheres* "The enlargement of the moon, the sun, and and the constellations at the horizon can be completely explained by the fact that they appear more distant than the objects interposed, and we thus judge them to be larger because we instinctively compare them with houses, trees, hills, etc., while when isolated in the heights of the empty sky we judge them to be much nearer. The apparently lowered vault of the sky and this removal in distance are due to the same optical effect, the same illusion."

And this is the *résumé* of what we said here at our 1911 meetings:

"It is incontestable that the sun and the full moon appear much larger when they are rising or setting than when at a certain height in the heavens, perhaps two or three times as great in diameter, in a really colossal proportion. The same thing is true of the constellations. Orion is gigantic, and that indeed is the origin of his appellation. But this enlargement is only apparent, due principally to the form of the flattened vault of the sky, which enlarges the projection of the angles from the zenith to the horizon.

"Look at the sky in cloudy weather and you will perceive that the clouds situated above our heads are much nearer us than those at the horizon. The cumulus clouds float at 1000, 1200, 1500 meters above our heads, while the horizon is 5, 6, 10, 15, or 20 kilometers distant or more, according to the place of observation. From my observatory at Juvisy, for example, we see the Eiffel Tower 20 kilometers distant. From the ramparts of the city of Langres Mont Blanc can be seen, at a distance of 245 kilometers. The apparent sky is therefore an almost flat roof not bending downward except at a great distance. The far clouds seem poised upon the horizon. Thence results this vault in the form of a furnace, this flattened pressed vault to which we are accustomed, and which does not differ very much even in the clearest sky, because of the accustomedness of the eye and because of the degradation of the color from blue to gray."

The sides of the angles drawn from the center of the celestial hemisphere to its circumference diverge from the zenith to the horizon as they cut this flattened vault, as can easily be seen in Fig. 1, which was published in the first edition (1872) of my work, *L'Atmosphere.*

This figure which resembles that of Malebranche, so brilliantly commented on the other day by Dr. Dubief, was drawn by Robert Smith in his *Course on Optics* (London, 1738), translated into French by Pezenas in 1767, and published by Voltaire in his *Dictionnaire philosophique* under the work "Sky."

Smith concluded from his comparisons that the sky appears three or four times as far from us at the horizon as at the zenith in the proportion of the figure, and that apparent diameters of the moon and sun vary in the following ratios with their height:

Heights of Sun and of Moon	Apparent Diameters
0°	100
15	68
30	50
45	40
60	34
75	31
90	30

The effect is the same for the apparent angular distances of the stars and for the size of the constellations.

It has always seemed to me that we could adopt this explanation.

But are there additional causes? In particular, does the atmosphere produce the effect of a magnifying glass, as maintained by M. Saint-Saëns? It was my desire once more to test

*Translated for the Scientific American Monthly from *L'Astronomie.*

the ideas of an observer meriting such a high degree of consideration. A perpetual demonstration o fthis absence of enlargement had already been furnished by the fact that the measurement of the lunar circles or of the sun spots is not affected by the height of the star above the horizon, except for the well known correction for refraction, which does not change the horizontal diameters, and actually *diminishes* the vertical diameter; but another demonstration, even easier and simpler can be given by photography.

To judge directly whether the sun and the moon are larger when near the horizon, by reason of an optical phenomenon due to the atmosphere acting like a magnifying glass isn't the simplest plan to photograph them? We have done this at the

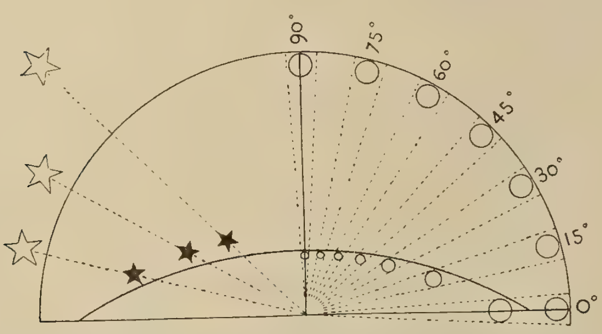


FIG. 1. EXPLAINING THE APPARENT ENLARGEMENT OF THE STARS NEAR THE HORIZON BY THE FLATTENED SHAPE OF THE CELESTIAL VAULT

Juvisy Observatory. Thanks to the well known skill of M. Quénisset many of these photographs were a perfect success in spite of the red colorations which are so poorly photogenic, as borne witness to below:

"The first photograph, reproduced above (Fig. 2) caught the sun near its setting in five successive exposures at intervals of about two minutes; we see plainly that there is absolutely no increase in size as the horizon is approached. The "disks become flattened, because of the refraction, in proportion as the sun sinks in the west, but the horizontal diameter remains the same. The dimension of the solar disk even appears to diminish as it descends because of its diminution in brilliance.

The second photograph (Fig. 3) represents the moon rising in the sky, and portrays itself as a path of uninterrupted light, extending to the top of the plate, in the apparatus, which remained open for two hours. We perceive that by a phenomenon analogous to the preceding, this path will seem rather to become wider because of the luminous intensity which increases with the purity of the atmosphere. There is also an effect due to the deformation introduced by the best objectives. The real image remains the same.

Conclusion: In reality the sun and the moon are not two or three times as large at the horizon as in the heights of the sky, though they appear to be; they are not even one fourth, one tenth, or any other fraction larger. The appearance is nothing but an optical illusion.

By reason of the parallax of the moon and of its considerably greater distance at the horizon than when it is at the zenith, by the entire length of the semi-diameter of the earth, it really shows itself as smaller at the horizon than at the meridian, in the proportion of a sixtieth or a half-minute of an arc. This variation is in the contrary direction to the apparent variation. It is not perceptible to our eyes.

It might be thought that our photograph bears evidence to this, for it here measures three millimeters below and three and one-half millimeters above, but I attribute this enlargement of the ribbon to the increase in the light of the moon in proportion as it rises in the sky. Is the apparent increase in size influenced by other causes than the geometrical form of the firmament?

The red coloration of the sun and the moon at the horizon, in contrast with the misty blue of the layers of air, the vague aspect of a semi-transparent atmosphere without precise limits, possibly play some part in this illusion[1].

Variations in the transparency of the air must play a nonnegligible part, but always one of optical nature, producing contrasting effects upon our retina. Moreover, these variations may elongate the distance of the horizon, *i.e.*, flatten still more the celestial vault and *increase the apparent* size of the disks of the sun and moon at the horizon. The apparent changes in dimension and the difference of visibility may have still other causes.

Apropos of this, here is the letter I received from M. Saint-Saëns in the spring of 1911:

"My dear Flammarion: Excuse me if I till insist upon this question of the enlargement of objects near the horizon, by reason of observations which I have made upon this subject, every time I have had the opportunity, for a number of years.

"The flattened appearance of the vault of the sky explains perfectly, as you have said, the enlargement of the stars and constellations; but this appearance is not subject to variations; its effect should be always identical. But this is not the case. The enlargement observed is of variable nature. Hence there must be another cause which superposes itself upon that which you have so justly indicated.

"This cause is the effect of the 'magnifying glass' produced by the atmosphere under certain conditions, an effect which some hesitate to admit. These conditions, which remain to be determined, appear to me to be a special hygrometric state, a sort of transparent fog permitting objects to be clearly seen; but I cannot affirm the truth of this supposition. What I believe I can affirm is that the ordinary explanation is not sufficient in certain cases. It does not explain the enlargement of boats at a relatively short distance, and particularly why this increase in size is not always produced. It does not explain why it was that on one occasion, when I happened to be

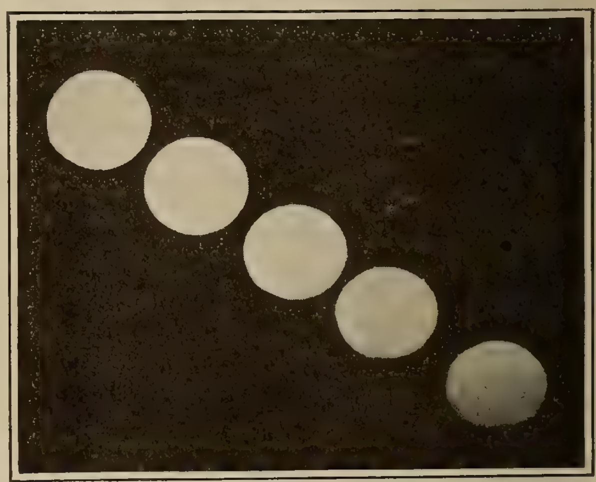


FIG. 2. THE SUN'S DISK PHOTOGRAPHED WHILE SETTING

on a boat in the Suez Canal, the City of Port Said seemed to all the passengers to be quite near because of the size of the buildings that compose it, but was suddenly reduced in volume and relegated to its true position.

"It does not explain how it was that one day, being on the shores of Lake Leman with two companions we suddenly saw an enormous grayish balloon ascend between two mountains, whose dimensions were so great and whose ascent was so rapid that it was three or four seconds before we recognized it to be the moon, whereafter it suddenly and markedly diminished in speed and dimensions.

"Finally, it does not explain why the moon, even at a considerable height above the horizon seems much larger on certain days than it usually does.

[1] See also what I wrote in the Bulletin for Nov., 1913, p. 500, as well as the quotation I have made fom Malebranche, 1912, pp. 489 and 539.

"An ignorant person like myself can only observe attentively and recount faithfully what he has seen. If he ventures, later, to risk the making of hypotheses, he may offer the excuse that some great savants have done the same and failed to have them confirmed by the facts. But he would be happy if he could instigate the savants to direct their attention to the phenomena which he has observed and themselves observe these with the competence which he himself lacks."

C. Saint-Saëns is too modest with respect to his own appraisal of himself, for we all hold him in high esteem; but he is, like us, capable of error, and we may remark, in answer to his first objection, that the appearance of the celestial vault *varies*.

Moreover, he invites the thought that the atmosphere at times plays an indeterminate rôle, and that in the Port Said case, for example, there may have been produced some effect of *mirage*.

We may also accept the views of Dr. Dubief with respect to the effects of binocular vision.

But so far as the enlargement of the stars is concerned

FIG. 3. PHOTOGRAPHIC PATH OF THE RISING MOON

it is certain that there is optical illusion. We do not really see the stars larger—we *believe* we see them larger. We deal here with a *psychological* fact, which is none the less interesting for our general instruction.

I recall that a few years ago a member of the *Société Scientifique Flammarion*, of Marseilles wrote to us that one evening in the port of that city, after having fixed his gaze upon the ruddy sun setting in splendor above the sea, he looked by chance at a point near the zenith—and perhaps taken as the zenith, according to the judicious remarks of M. Fouché—and that he was surprised, while seeing the blue complementary image clearly defined upon the vault of the sky, to note that it was only a half or a third as large as that of the red sun upon the horizon. Upon his retina, therefore, it did not possess the apparent dimensions.

Here is another image (Fig. 4) which confirms our reasoning. If we draw two equal circles in the interior of an angle, one near the apex, the other farther off the first will always appear the larger, because of the vicinity of the sides of the angle. The full moon, upon the horizon presents itself within the angle formed by the line of the earth and the apparent vault of the sky. The variations of this angle according to the aspect of the sky at the horizon may explain the variations in the apparent size of the moon at the time of its rise. But this is always an instance of optical illusion.

In my *Annuaire Astronomique* for 1913 I published, in the "*Scientific Recreations*," another sort of figure likeness showing the effects of an optical illusion (Fig. 5). Which is the longer, the distance between A and B, or that between C and D? It is exactly the same. If the former appears longer it is because the space between is empty.

These projections, for which I am indebted to our devoted

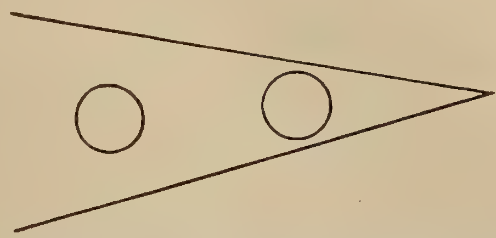


FIG. 4. AN OPTICAL ILLUSION. THE CIRCLE NEARER THE VERTEX APPEARS LARGER THAN THE OTHER

colleague, M. André Bloch, will make the latter, I believe, incontestably obvious to all eyes.

It appears to be definitely demonstrated, therefore, that the enlargement of the full moon and the sun at the time of rising and setting, as also that of the constellations at 20 or 30 degrees above the horizon, is nothing but an optical illusion.

One last objection: It has been said also that the sun and the full moon seem larger to us at the horizon simply because we see better that which is directly in front of us. Nearly everything which presents itself directly to our gaze diverges very slightly from the level of our eyes, and is situated at relatively small angular distances above or below the horizontal plane. Our visual faculty being highly developed in this direction the objects viewed thus appear larger than when seen in the other positions which they occupy with respect to our own.

This explanation may be disputed. A tree, fallen and lying upon the earth looks as large as when standing. The Eiffel Tower laid horizontally upon the ground, would seem even larger, for it would be necessary to walk 300 meters to traverse the whole extent. It is a question of the angle and the distance.

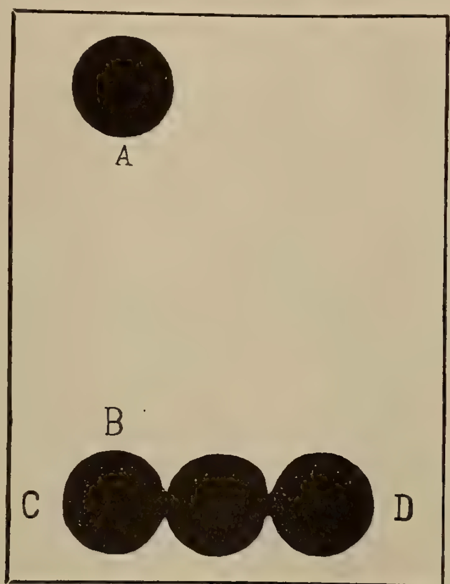


FIG. 5. ANOTHER ILLUSION IN WHICH THE EQUAL DISTANCES A B AND C D APPEAR UNEQUAL

In conclusion, therefore, we may say that the apparent form of the sky is sufficient by itself to explain the proportional enlargement of the stars and constellations upon their approach to the horizon.

Einstein's Relativity Theory of Gravitation*

A Popular Explanation

By E. Cunningham

THE results of the Solar Eclipse Expeditions announced at the joint meeting of the Royal Society and Royal Astronomical Society on November 6 brought for the first time to the notice of the general public the consummation of Einstein's new theory of gravitation. The theory was already in being before the war; it is one of the few pieces of pure scientific knowledge which have not been set aside in the emergency; preparations for this expedition were in progress before the war had ceased.

Before attempting to understand the theory which, if we are to believe the daily press, has dimmed the fame of Newton, it may be worth while to recall what it was that he did. It was not so much that he, first among men, used the differential calculus. That claim was disputed by Leibniz. Nor did he first conceive the exact relations of inertia and force. Of these, Galileo certainly had an inkling. Kepler, long before, had a vague suspicion of a universal gravitation, and the law of the inverse square had, at any rate, been mooted by Hooke before the "Principia" saw the light. The outstanding feature of Newton's work was that it drew together so many loose threads. It unified phenomena so diverse as the planetary motions, exactly described by Kepler, the everyday facts of falling bodies, the rise and fall of the tides, the top-like motion of the earth's axis, besides many minor irregularities in lunar and planetary motions. With all these drawn into such a simple scheme as the three laws of motion combined with the compact law of the invese square, it is no wonder that flights of speculation ceased for a time. The universe seemed simple and satisfying. For a century at least there was little to do but formal development of Newton's dynamics. In the mid-eighteenth century Maupertuis hinted at a new physical doctrine. He was not content to think of the universe as a great clock the wheels of which turned inevitably and irrevocably according to a fixed rule. Surely there must be some purpose, some divine economy in all its motions. So he propounded a principle of least action. But it soon appeared that this was only Newton's laws in a new guise; and so the eighteenth century closed.

The nineteenth saw great changes. When it closed, the age of electricity had come. Men were peering into the secrets of the atom. Space was no longer a mighty vacuum in the cold emptiness of which rolled the planets. It was filled in every part with restless energy. Æther, not matter, was the last reality. Mass and matter were electrical at bottom. A great problem was set for the present generation; to reconcile one with the other the new laws of electricity and the classical dynamics of Newton. At this point the principle of least action began to assume greater importance; for the old and the new schemes of the universe had this in common, that in each of them the time average of the difference between the kinetic and the potential energies appears to be a minimum.

One of the main difficulties encountered by the electrical theory of matter has been the obstinate refusal of gravitation to come within its scope. Quietly obeying the law of the inverse square, it heeded not the bustle and excitement of the ne wphysics of the atom, but remained, independent and inevitable, a constant challenge to rash claimants to the key of the universe. The electrical theory seemed on the way to explain every property of matter yet known, except the one most universal of them all. It could trace to its origins the difference between copper and glass, but not the common fact of their weight; and now the ether began silently to steal away.

*Reprinted from *Nature* (London).

One matter that has seriously troubled men in Newton's picture of the universe is its failure to accord with the philosophic doctrine of the relativity of space and time. The vital quantity in dynamics is the acceleration, the change of motion of a body. This does not mean that Newton assumed the existence of some ultimate framework in space relative to which the actual velocity of a body can be uniquely specified, for no difference is made to his laws if any arbitrary constant velocity is added to the velocity of every particle of matter at all time. The serious matter is that the laws cannot possibly have the same simplicity of form relative to two frameworks of which one is in rotation or non-uniform motion relative to the other. It seems, for instance, that if Newton were right, the term "fixed direction" in space means something, but "fixed position" means nothing. It seems as if the two must stand or fall together. And yet the physical relations certainly make a distinction. Why this should be so has not yet been made known to us. Whatever new theory we adopt must take account of the fact.

It was with some feeling of relief that men hailed the advent of the ether as a substitute for empty space, though we may note in passing that some philosophers—Comte, for example—have held that the concept of an ether, infinite and intangible, is as illogical as that of an absolute space. But, jumping at the notion, physicists proposed to measure all velocities and rotations relative to it. Alas! the ether refused to disclose the measurements. Explanations were soon forthcoming to account for its reluctance; but these were so far-reaching that they explained away the ether itself in the sense in which it was commonly understood. At any rate, they proved that this creature of the scientific imagination was not one, but many. It quite failed to satisfy the cravings for a permanent standard against which motion might be measured. The problem was left exactly where it was before. This was pre-war relativity, summarized by Einstein in 1905. The physicists complained loudly that he was taking away their ether.

Let it not be thought, however, that the results of the hypothesis then advanced were purely negative. They showed quite clearly that many current ideas must be modified, and in what direction this must be done. Most notably it emphasized the fact that inertia is not a fundamental and invariable property of matter; rather it must be supposed that it is consequent upon the property of energy. And, again, energy is a relative term. One absolute quantity alone remained; one only stood independent of the taste or fancy of the observer, and that was "action." While the ether and the associated system of measurement could be selected as any one of a legion, the principle of least action was satisfied in each of them, and the magnitude of the action was the same in all.

But, still, gravitation had to be left out; and the question from which Einstein began the great advance now consummated in success was this. If energy and inertia are inseparable, may not gravitation, too, be rooted in energy? If the energy in a beam of light has momentum, may it not also have weight?

The mere thought was revolutionary, crude though it be. For if at all possible it means reconsidering the hypothesis of the constancy and universality of the velocity of light. This hypothesis was essential to the yet infant principle of relativity. But if called in question, if the velocity of light is only approximately constant because of our ordinary ways of measuring, the principle of relativity, general as it is, becomes itself an approximation. But to what? It can only be to something more general still. Is it possible to maintain

anything at all of the principle with that essential limitation removed?

Here was exactly the point at which philosophers had criticized the original work of Einstein. For the physicist it did too much. For the philosopher it was not nearly drastic enough. He asked for an out-and-out relativity of space and time. He would have it that there is no ultimate criterion of the equality of space intervals or time intervals, save complete coincidence. All that is asked is that the order in which an observer perceives occurrences to happen and objects to be arranged shall not be disturbed. Subject to this, any way of measuring will do. The globe may be mapped on a Mercator projection, a gnomonic, a stereographic, or any other projection; but no one can say that one is a truer map than another. Each is a safe guide to the mariner or the aviator. So there are many ways of mapping out the sequences of events in space and time, all of which are equally true pictures and equally faithful servants.

This, then, was the mathematical problem presented to Einstein and solved. The pure mathematics required was already in existence. An absolute differential calculus, the theory of differential invariants, was already known. In pages of pure mathematics that the majority must always take as read, Riemann, Christoffel, Ricci, and Levi-Civita supplied him with the necessary machinery. It remained out of their equations and expressions to select some which had the nearest kinship to those of mathematical physics and to see what could be done with them.

THE NATURE OF THE THEORY.

We have attempted to show the roads which led to Einstein's adventure of thought. On the physical side briefly it was this. Newton associated gravitation definitely with mass. Electromagnetic theory showed that the mass of a body is not a definite and invariable quantity inherent in matter alone. The energy of light and heat certainly has inertia. Is it, then, also susceptible to gravitation, and, if so, exactly in what manner? The very precise experiments of Eötvös rather indicated that the mass of a body, as indicated by its inertia, is the same as that which is affected by gravitation.

Also, how must the expression of Newton's law of gravitation be modified to meet the new view of mass? How, also, must the electromagnetic theory and the related pre-war relativity be adapted to allow of the effect of gravitation? With the relaxation of the stipulation that the velocity of light shall be constant, will the principle of relativity become more general and acceptable to the philosophic doctrine of relativity, or will it, on the other hand, become completely impossible?

One point arises immediately. The out-and-out relativist will not admit an absolute measure of acceleration any more than of velocity. The effect, however, of an accelerated motion is to produce an apparent change in gravitation; the measure of gravitation at any place must therefore be a relative quantity depending upon the choice which the observer makes as to the way in which he will measure velocities and accelerations. This is one of Einstein's fundamental points. It has been customary in expositions of mechanics to distinguish between so-called "centrifugal force" and "gravitational force." The former is said to be fictitious, being simply a manifestation of the desire of a body to travel uniformly in a straight line. On the other hand, gravitation has been called a real force because associated with a cause external to the body on which it acts.

Einstein asks us to consider the result of supposing that the distinction is not essential. This was his so-called "principle of equivalence." It led at once to the idea of a ray of light being deviated as it passes through a field of gravitational force. An observer near the surface of the earth notes objects falling away from him towards the earth. Ordinarily, he attributes this to the earth's attraction. If he falls with them, his sense of gravitation is lost. His watch ceases to press on the bottom of his pocket; his feet no longer press on his boots. To this falling observer there is no gravitation. If he had time to think or make observations of the propagation of light, according to the principle of equivalence he would now find nothing gravitational to disturb the rectilinear motion of light. In other words, a ray of light propagated horizontally would share in his vertical motion. To an observer not falling, and, therefore, cognizant of a gravitational field, the path of the ray would therefore be bending downward towards the earth.

The systematic working out of this idea requires, as has been remarked, considerable mathematics. All that can be attempted here is to give a faint indication of the line of attack, mainly by way of analogy.

It is no new discovery to speak of time as a fourth dimension. Every human mind has the power in some degree of looking upon a period of the history of the world as a whole. In doing this, little difference is made between intervals of time and intervals of space. The whole is laid out before him to comprehend in one glance. He can at the same time contemplate a succession of events in time, and the spatial relations of those events. He can, for instance, think simultaneously of the growth of the British Empire chronologically and territorially. He can, so to speak, draw a map, a four-dimensional map, incapable of being drawn on paper, but none the less a picture of a domain of events.

Let us pursue the map analogy in the familiar two-dimensional sense. Imagine that a map of some region of the globe is drawn on some material capable of extension and distortion without physical restriction save that of the preservation of its continuity. No matter what distortion takes place, a continuous line marking a sequence of places remains continuous, and the places remain in the same order along that line. The map ceases to be any good as a record of distance travelled, but it invariably records certain facts, as, for example, that a place called London is in a region called England, and that another place called Paris cannot be reached from London without crossing a region of water. But the common characteristic of maps of correctly recording the shape of any small area is lost.

The shortest path from any place on the earth's surface to any other place is along a great circle; on all the common maps, one series of great circles, the meridians, is mapped as a series of straight lines. It might seem at first sight that our extensible map might be so strained that all great circles on the earth's surface might be represented by straight lines. But, as a matter of fact, this is not so. We might represent the meridians and the great circles through a second diameter of the earth as two sets of straight lines, but then every other great circle would be represented as a curve.

The extension of this to four dimensions gives a fair idea of Einstein's basic conception. In a world free from gravitation we ordinarily conceive of free particles as being permanently at rest or moving uniformly in straight lines. We may imagine a four-dimensional map in which the history of such a particle is recorded as a straight line. If the particle is at rest, the straight line is parallel to the time axis; otherwise it is inclined to it. Now if this map be strained in any manner, the paths of particles are no longer represented as straight lines. Any person who accepts the strained map as a picture of the facts may interpret the bent paths as evidence of a "gravitational field," but this field can be explained right away as due to his particular representation, for the paths can all be made straight.

But our two-dimensionl analogy shows that we may conceive of cases where no amount of straining will make all the lines that record the history of free particles simultaneously straight; pure mathematics can show the precise geometrical significance of this, and can write down expressions which may serve as a measure of the deviations that cannot be

removed. The necessary calculus we owe to the genius of Riemann and Christoffel.

Einstein now identifies the presence of curvatures that cannot be smoothed out with the presence of matter. This means that the vanishing of certain mathematical expressions indicates the absence of matter. Thus he writes down the laws of the gravitational field in free space. On the other hand, if the expressions do not vanish, they must be equal to quantities characteristic of matter and its motion. These equalities form the expression of his law of gravitation at points where matter exists.

The reader will ask: What are the quantities which enter into these equations? To this only a very insufficient answer can here be given. If, in the four-dimensional map, two neighboring points be taken, representing what may be called two neighboring occurrences, the actual distance between them measured in the ordinary geometrical sense has no physical meaning. If the map be strained, it will be altered, and therefore to the relativist it represents something which is not in the external world of events apart from the observer's caprice of measurement. But Einstein assumes that there is a quantity depending on the relation of the points one to the other which is invariant—that is, independent of the particular map of events. Comparing one map with another, thinking of one being strained into the other, the relative positions of the two events are altered as the strain is altered. It is assumed that the strain at any point may be specified by a number of quantities (commonly denoted g_{rs}), and the invariable quantity is a function of these and of the relative positions of the points. It is these quantities g which characterize the gravitational field and enter into the differential equations which constitute the new law of gravitation.

It is, of course, impossible to convey a precise impression of the mathematical basis of this theory in non-mathematical terms. But the main purpose of this article is to indicate its very general nature. It differs from many theories in that it is not devised to meet newly observed phenomena. It is put together to satisfy a mental craving and an obstinate philosophic questioning. It is essentially pure mathematics. The first impression on the problem being stated is that it is incapable of solution; the second of amazement that it has been carried through; and the third of surprise that it should suggest phenomena capable of experimental investigation.

THE CRUCIAL PHENOMENA.

As Minkowski remarked in reference to Einstein's early restricted principle of relativity: "From henceforth, space by itself and time by itself do not exist; there remains only a blend of the two" ("Raum und Zeit," 1908). In this four-dimensional world that portrays all history let (x_1, x_2, x_3, x_4) be a set of coördinates. Any particular set of values attached to these coördinates marks an event. If an observer notes two events at neighboring places at slightly different times, the corresponding points of the four-dimensional map have coördinates slightly differing one from the other. Let the differences be called (dx_1, dx_2, dx_3, dx_4). Einstein's fundamental hypothesis is this: there exists a set of quantities g_{rs} such that

$$g_{11}dx_1^2 + 2g_{12}dx_1dx_2 + \ldots + g_{44}dx_4^2$$

has the same value, no matter how the four-dimensional map is strained. In any strain g_{rs} is, of course, changed, as are also the differences dx.§

If the above expression be denoted by $(ds)^2$, ds may conveniently be called the *interval* between two events (not, of course, in the sense of time interval). In the case of a field in which there is no gravitation at all, if dx_4 is taken to be dt, it is supposed that ds^2 reduces to the expression $dx_1^2 + dx_2^2 + dx_3^2 - c^2dt^2$. where c is the velocity of light. If this is put equal to zero, it simply expresses the condition that the neighboring events correspond to two events in the history of a point travelling with the velocity of light.

§The gravitational field is specified by the set of quantities grs. When the gravitational field is small, these are all zero, except for $g44$, which is approximately the ordinary Newtonian gravitational potential.

Einstein is now able to write down differential equations connecting the quantities g_{rs} with the coördinates (x_1, x_2, x_3, x_4), which are in complete accord with the requirement of complete relativity.[1] These equations are assumed to hold at all points of space unoccupied by matter, and they constitute Einstein's law of gravitation.

PLANETARY MOTION.

The next step is to find a solution of the equations when there is just one point in space at which matter is supposed to exist, one point which is a singularity of the solution. This can be effected completely:[2] That is, a unique expression is obtained for the interval between two neighboring events in the gravitational field of a single mass. This mass is now taken to be the sun.

It is next assumed that in the four-dimensional map (which by the way, has now a bad twist in it, that cannot be strained out, all along the line of points corresponding to the positions of the sun at every instant of time) the path of a particle moving under the gravitation of the sun will be the most direct line between any two points on it, in the sense that the sum of all the intervals corresponding to all the elements of its path is the least possible.[3] Thus the equations of motion are written down. The result is this: *The motion of a particle differs only from that given by the Newtonian theory by the presence of an additional acceleration towards the sun equal to three times the mass of the sun (in gravitational units) multiplied by the square of the angular velocity of the planet about the sun.*

In the case of the planet Mercury, this new acceleration is of the order of 10^{-8} times the Newtonian acceleration. Thus up to this order of accuracy Einstein's theory actually arrives at Newton's laws: surely no dethronement of Newton.

The effect of the additional acceleration can easily be expressed as a perturbation of the Newtonian elliptic orbit of the planet. It leads to the result that the major axis of the orbit must rotate in the plane of the orbit at the rate of 42.9″ per century.

Now it has long been known that the perihelion of Mercury does actually rotate at the rate of about 40″ per century, and Newtonian theory has never succeeded in explaining this, except by *ad hoc* assumptions of disturbing matter not otherwise known.

Thus Einstein's theory almost exactly accounts for the one outstanding failure of Newton's scheme, and, we may note, does not introduce any discrepancy where hitherto there was agreement.

THE DEFLECTION OF LIGHT BY GRAVITATION.

The new theory having justified itself so far, it was thought worth while for British astronomers to devote their main energies at the recent solar eclipse to testing its prediction of an entirely new phenomenon.

As was remarked above, the propagation of light in the ordinary case of freedom from gravitational effect is represented by the equation $ds=o$.

This Einstein boldly transfers to his generalized theory. After all, it is quite a natural assumption. The propagation of light is a purely objective phenomenon. The emission of

[1] These equations take the place of the old Laplace equation $\nabla^2V=o$. Just as that equation is the only differential equation of the second order which is entirely independent of any change of ordinary space co-ordinates, so Einstein equations are uniquely determined by the condition of relativity.

[2] The result is that the invariant interval ds is given by

$$ds^2=(1-2m/r)(dt^2-dr^2)-r^2(d\theta^2+\sin^2\theta d\phi^2),$$

the four co-ordinates being now interpreted as time and ordinary spherical polar co-ordinates.

[3] This corresponds to the fact that in a field where there is no acceleration at all the path of a particle is the shortest distance between two points.

a disturbance from one point at another moment, are events distinct and independent of the existence of an observer. Any law that connects them must be one which is independent of the map the observer uses; ds being an invariant quantity, $ds=o$ expresses such an invariant law.

This leads at once to a law of variation of the velocity of light in the gravitational field of the sun.

$$v=c(1-2m/r).$$

Here m, as before, is the mass of the sun in gravitational units, and is equal to 1.47 kilometers, while c is the velocity of light at a great distance from the sun. Thus the path of a ray is the same as that if, on the ordinary view, it were travelling in a medium the refractive index of which was $(1-2m/r)^{-1}$. In this medium the refractive index would increase in approaching the sun, so that the rays would be bent round towards the sun in passing through it. The total amount of the deflection for a ray which just grazes the sun's surface works out to be 1.75″, falling off as the inverse of the distance of the nearest approach.

The apparent position of a star near to the sun is thus further from the sun's center than the true position. On the photographic plate in the actual observations made by the Eclipse Expedition the displacement of the star image is of the order of a thousandth of an inch. The measurements show without doubt such a displacement. The stars observed were, of course, not exactly at the edge of the sun's disk; but on reduction, allowing for the variation inversely as the distance, they give for the bend of a ray just grazing the sun the value 1.98″, with a probable error of 6 per cent, in the case of the Sobral expedition, and of 1.64″ in the Principe expedition.

The agreement with the theory is close enough, but, of course, alternative possible causes of the shift have to be considered. Naturally, the suggestion of an actual refracting atmosphere surrounding the sun has been made. The existence of this, however, seems to be negatived by the fact that an atmosphere sufficiently dense to produce the refraction in question would extinguish the light altogether, as the rays would have to travel a million miles or so through it. The second suggestion, made by Prof. Anderson in *Nature* of December 4, that the observed displacement might be due to a refraction of the ray in travelling through the earth's atmosphere in consequence of a temperature gradient within the shadow cone of the moon, seems also to be negatived. Prof. Eddington estimates that it would require a change of temperature of about 20° C. per minute at the observing station to produce the observed effect. Certainly no such temperature change as this has ever been noted; and, in fact, in Principe, at which the Cambridge expedition made its observations, there was practically no fall of temperature.

GRAVITATION AND THE SOLAR SPECTRUM.

It was suggested by Einstein that a further consequence of his theory would be an apparent discrepancy of period between the vibrations of an atom in the intense gravitational field of the sun and the vibrations of a similar atom in the much weaker field of the earth. This is arrived at thus. An observer would not be able to infer the intensity of the gravitational field in which he was placed from any observations of atomic vibrations in the same field; that is, an observer on the sun would estimate the period of vibrations of an atom there to be the same that he would find for a similar atom in the earth's field if he transported himself thither. But on transferring himself he automatically changes his scale of time; in the new scale of time the solar atom vibrates differently, and, therefore, is not synchronous with the terrestrial atom.

Observations of the solar spectrum so far are adverse to the existence of such an effect. What, then, is to be said? Is the theory wrong at this point? If so, it must be given up, in spite of its extraordinary success in respect of the other two phenomena.

Sir Joseph Larmor, however, is of opinion that Einstein's theory itself does not in reality predict the displacement at all. The present writer shares his opinion. Imagine, in fact, two identical atoms originally at a great distance from both sun and earth. They have the same period. Let an observer A accompany one of these into the gravitational field of the sun, and an observer B accompany the other into the field of the earth. In consequence of A and B having moved into different gravitational fields, they make different changes in their scales of time, so that actually the solar observer A will find a different period for the solar atom from that which B, on the earth, attributes to his atom. It is only when the two observers choose so to measure space and time that they consider themselves to be in identical gravitational fields that they will estimate the periods of the atoms alike. This is exactly what would happen if B transferred himself to the same position as A. Thus, though an important point remains to be cleared up, it cannot be said that it is one which at present weighs against Einstein's theory.

THE RESPONSE OF PLANTS TO WIRELESS STIMULATION*

By J. C. Bose.

A GROWING plant bends towards light; this is true, not only of the main stem, but also of its branches and attached leaves and leaflets. This movement in response is described as the tropic effect of light. Growth itself is modified by the action of light: two different effects depending on the intensity are produced; strong stimulus of light causes a diminution of rate of growth, but very feeble stimulus induces an acceleration of growth. The tropic effect is very strong in the ultraviolet region of the spectrum with its extremely short wavelength of light; but the effect declines practically to zero as we move towards the less refrangible rays, the yellow and the red, with their comparatively long wave-length. As we proceed further in the infra-red region we come across the vast range of electric radiation, the wave-lengths of which vary from the shortest wave I have been able to produce (0.6 cm.) to others which may be miles in length. There thus arises the very interesting question whether plants perceive and respond to the long ether-waves, including those employed in signalling through space.

At first sight this would appear to be very unlikely, for the most effective rays are in the ultra-violet region with wave-length as short as 20×10^{-6} cm.; but with electric waves used in wireless signalling we have to deal with waves 50,000,000 times as long. The perceptive power of our retina is confined within the very narrow range of a single octave, the wavelengths of which lie between 70×10^{-6} cm. and 35×10^{-6} cm. It is difficult to imagine that plants could perceive radiations so widely separated from each other as the visible light and the invisible electric waves.

But the subject assumes a different aspect when we take into consideration the total effect of radiation on the plant. Light induces two different effects which may broadly be distinguished as external and internal. The former is visible as movement; the latter finds no outward manifestation, but consists of an "up" or assimilatory chemical change with concomitant increase of potential energy. Of the two reactions, then, one is dynamic, attended by dissimilatory "down" change; the other is potential, associated with the opposite "up" change. In reality, the two effects take place simultaneously; but one of them becomes predominant under definite conditions.

The modifying condition is the *quality* of light. With reference to this I quote the following from Pfeffer:—"So far as is at present known, the action of different rays of the spectrum gives similar curves in regard to heliotropic and phototactic movements, to protoplasmic streaming and movements of the

* From *Nature* (London).

chloroplastids, as well as the photonastic movements produced by growth or by changes of turgor. On the other hand, it is the less refrangible rays which are most active in photosynthesis."[1] The dynamic and potential manifestations are thus seen to be complementary to each other, the rays which induce photosynthesis being relatively ineffective for tropic reaction, and *vice versa.*

Returning to the action of electric waves, since they exert no photosynthetic action they might conceivably induce the complementary tropic effect. These considerations led me to

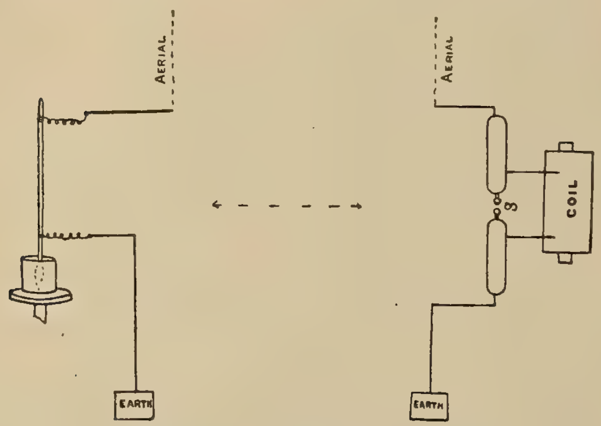


FIG. 1. DIAGRAMMATIC REPRESENTATION OF THE METHOD OF WIRELESS STIMULATION

On the right is seen the generating apparatus. The tip of the growing plant is connected with the receiving aerial, and the lower part of the flower-pot is earthed.

the investigation of the subject fourteen years ago, and my results showed that very short electric waves induce a retardation of rate of growth; they also produce responsive movements of the leaf of Mimosa when the plant is in a highly sensitive condition.[2] The energy of the short electric waves is very feeble, and undergoes great diminution at a distance; hence the necessity for employment of a specimen of plant in a highly sensitive condition.

I resumed my investigations on the subject at the beginning of this year. I wished to find out whether plants in general perceived and responded to long ether-waves reaching them from a distance. The perception of the wireless stimulation was to be tested, not merely by the responsive movement of sensitive plants, but also by diverse modes of response given by all kinds of plants.

THE WIRELESS SYSTEM.

For sending wireless signals I had to improvise the following arrangement, more powerful means not being available. The secondary terminals of a moderate-sized Ruhmkorff's coil were connected with two cylinders of brass, each 20 cm. in length; the sparking took place between two small spheres of steel attached to the cylinders. One of the two cylinders was earthed and the other connected with the aerial 10 meters in height. The receiving aerial was also 10 meters in height, and its lower terminal led to the laboratory, and connected by means of a thin wire with the experimental plant growing in a pot; this latter was put in electric connnection with the earth (Fig. 1). The distance between the transmitting and receiving aerial was about 200 meters, the maximum length permitted by the grounds of the institute.

I may state here that with the arrangement described above I obtained very definite mechanical and electric response to wireless impulse. For the former I employed the plant Mimosa; the latter effect was detected in all plants, sensitive and ordinary. Limitation of space will allow only a detailed description of the responsive modification of growth.[3]

[1] Pfeffer, "Physiology of Plasts," vol. ii., p. 104.

[2] Bose, "Plant Response," p. 618 (1905).

[3] A detailed account of the response of plants to wireless stimulation will be found in the Transactions of the Bose Institute, vol. ii., to be published in November, 1919.

EFFECT OF WIRELESS STIMULATION ON GROWTH.

For the detection of variation of growth it was necessary to devise the extremely sensitive balanced crescograph. In this apparatus a compensating movement is given to the plant-holder by which the plant subsides exactly at the same rate as its growth-elongation, so that the tip of the plant remains at the same point. This perfect balance is attained by a variable regulator. The compound magnifying lever attached to the plant records the movement of growth. Under exact balance the record is horizontal. Any induced acceleration of growth would upset the balance, with a resulting down record; induced retardation, on the other hand, would cause an upset in the opposite direction and an up curve. The results given below show that growing plants not only perceive, but also respond to the stimulus of electric waves. These effects were found in all growing plants. The following records were obtained with the seedlings of wheat:

Effect of Feeble Stimulus.—Experiment 1: I first studied the effect of feeble stimulus. This was secured by decreasing the energy of sparks of the radiator. The response was an acceleration of rate of growth as seen in Fig. 2, (*a*). This is analogous to the accelerating effect of light stimulation of subminimal intensity.

Effect of Strong Stimulus.—Experiment 2: The maximum energy radiated by my transmitter, as stated before, was only moderate. In spite of this, its effect on plants was exhibited in a very striking manner. The balance was immediately upset, indicating a retardation of the rate of growth. The latent period *i. e.*, the interval between the incident wave and the response, was only a few seconds (Fig. 2, (*b*)). The record given in the figure was obtained with the moderate magnification of 2,000 times only; but with my crescograph the magnification can easily be raised ten million times, and

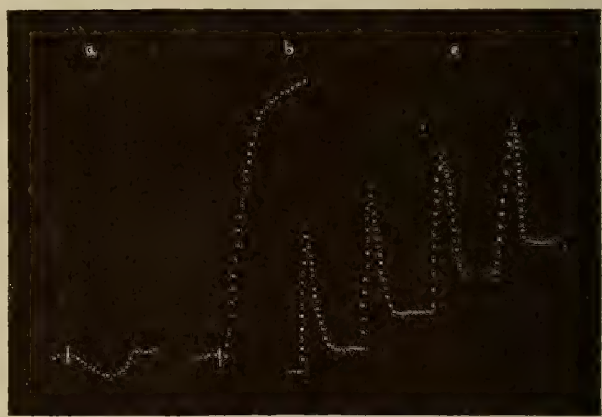


FIG. 2. AUTOMATIC RECORDS OBTAINED WITH THE BALANCED CRESCOGRAPH SHOWING THE EFFECTS OF WIRELESS STIMULATION ON GROWTH

(*a*) Feeble stimulus inducing acceleration; (*b*) strong stimulus inducing retardation of rate of growth; (*c*) series of growth responses by variation of growth due to uniform moderate stimulation. Up-curve represents retardation of growth and down-curve acceleration (seedling of wheat).

the perception of plant to the space-signalling can be exalted in the same proportion.

Under an intensity of stimulus slightly above the subminimal, the response exhibits retardation of growth followed by quick recovery, as seen in the series of records given in Fig. 2, (*c*). The perceptive range of the plant is inconceivably greater than ours; it not only perceives, but also responds to the different rays of the vast etheral spectrum.

PRESERVING EXPLOSIVES IN FRANCE

INSTEAD of storing her enormous stock of explosives (estimated value $140,000,000 to $150.000,000) in ordinary powder magazines and running the risk of disastrous explosions, France plans to submerge the stock in the cold lakes of the Pyrenees which are fed by glaciers.

FIG. 1. A CURIOUSLY VEINED KNOT ON A BEECH BRANCH

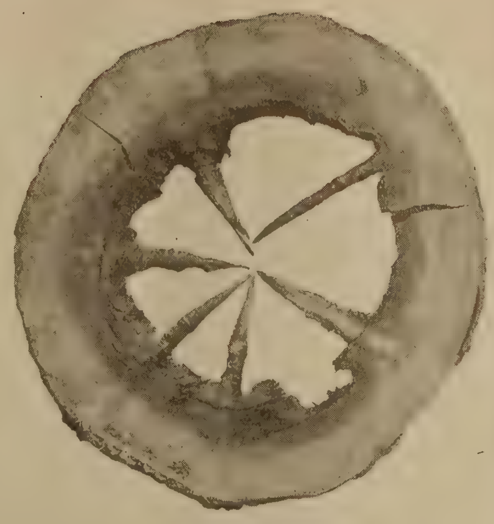


FIG. 2. SECTION OF A PINE DESTROYED BY WHAT APPEAR TO BE INGROWING BRANCHES

FIG. 3. A ROSE-LIKE TUMOR ON THE ROOT OF A VINE

Singular Phenomena in the Kingdom of Plants

Curious Vegetable Deformities

By Dr. Bergner

With Illustrations from Original Photographs Taken by the Author

THE remarkable phenomena shown in the accompanying illustrations are rather more plentiful in nature than might be thought. Many such things in fact remain hidden from us merely because they escape our unpracticed observation. Even in our own homes we sometimes fail to perceive, until it is too late, what an evil guest we have been harboring when we see the boards of the walls stained with dirty white or brownish flecks like tufts of cotton wool and realize that the "weeping fungus" (the *Merulius lacrymans*, also called dry-rot) which has already infested the house is at last showing its face. And yet we might have known what was going on had we but observed that the walls which at first were dry had become damp and then sent forth an evil reek. It is, in fact, a peculiarity of the house fungus which starts to grow in dark, damp places and spreads throughout the timbers of a house and through thick layers of mortar, that it constantly conducts water by means of its fibrous filaments from damp places to those which are still dry. If we go down into the cellar with a lamp in a house so infested we shall see hundreds of drops of water sparkling upon the woodwork. These are the "tears" which proceed from the fungus and to which our own may well be added, for this devil in the form of a fungus has brought ruin upon many a house. Again in the garden we may see close pressed fungi springing from the ground round about a fruit tree and bursting the bark of the latter. This is the "Hallimasch" a most vexatious evil-doer although it is a very appetizing bit of food; it is easily recognizable by its smooth brown cap, convex in the middle and bearing scales covered with dark hairs, by the white gills, of its lower side and by the thickening of the stalk where it issues from the grouid. But when we perceive it, it has long had its filaments or hyphae sunk into the roots of the tree which it destroys and these same fibers also penetrate the stem, which often withers in a single year from this cause. But not content with this it reaches out to lay hold upon the neighboring trees, unless it is combated by the most thorough-going uprooting of the tree originally affected. This fungus is particularly injurious in forests of evergreen trees. It is the filaments of this fungus, too, spun throughout fallen trees that occasion a phosphorescent gleam from rotting wood. It is a marvellous sight to see the floor of the forest shining with countless particles of light when one's foot happens to strike such a bit of wood.

There are other fungi which lack stems which are even more destructive, transforming the wood into a sort of red brown mold. On this account this disease is known as "red rot" and it sometimes lays low a whole section of a forest, even of an extent of 10 ar. or more in scarce so many years. In the meanwhile a tree thus attacked continues to remain green for a long time until some day when the work of destruction has reached its maximum, it suddenly collapses. This is core rot—the pine trunk whose cross section is shown in Fig. 2, has fallen a victim to this disease. It is so striking in this instance that the branches have apparently turned inward, thus giving the impression of a wheel which lacks only the hub of the axle. Curious enough are the witches' brooms, which were once thought by common folk to represent an injury done the trees by those unholy dames who used to ride through the air towards the Hartz Mountains upon brooms. In the winter these resemble bushy brooms since in contrast to their hosts, the evergreen trees, they drop their yellowish green needles which encircle the twig. But the affected tuft continues to grow for many years longer, finally resembling a small separate tree, as shown in Fig. 4, springing from the bough. Such abnormal growths in the family of firs are due to a microscopically

small fungus. Other mischief makers of similar nature attack deciduous trees and even fruit trees. The witches' brooms are especially harmful to our cherry trees since they never bear flowers but usually appear entirely covered with green foliage in the midst of a white sea of cherry blossoms.

The same parasite shown in the witches' broom grows upon the stately white fir which forms whole forests in the region of the Black Forest and the Vogesen causing a barrel like swelling of the stem and upon the branches, through whose deeply furrowed cracked bark, the wood is often exposed, so that it rots and is broken by storms. Within their midst these cancer like growths show filaments similarly arranged like the veined knots of our deciduous trees which certainly owe their origin to other causes. The nature of these is not yet fully understood, but a part is certainly played by injuries, such as the sawing off of branches, especially by reason of the fact that at such points the appearance of numerous lateral buds is favored by the increased flow of sap. It is true that the more plentiful these buds the sooner they die, but it is just these closely compacted remnants which form a serious obstruction to the new growth of wood so that its fibers become seriously twisted. This is the occasion of circular formations surrounding knots, of the handsome curved lines and the curious convolutions—in short of the handsome marking in veined hard wood which is the delight of cabinetmakers. Such twists and knots are found in the linden and the ash as also in the chestnut, the beech, the oak, and many other trees; very often these knots partly or even entirely encircle the trunk and naturally rob the tree of much nourishment without, however, killing it. In many sorts of timber such knots are frequently found in the roots also, especially in those fruit trees bearing fruit with kernels, being occasioned sometimes in the first year of the tree's life through the cutting or bruising of the roots when the young tree is transplanted.

The most remarkable phenomena of this sort, however, is the "timber rose" (Fig. 5), which resembles a bit of carving done by the hand of an artist, but which is caused by the irritation produced by a tree parasite, the Loranthus which grows upon the fallen bough. This family, which is found abundantly in the tropics also has a representative in Germany, the mistletoe, whose evergreen foliage greets us in winter upon the bare tree tops. At this time it bears white berries which gleam like pearls amid the green gold leaves. If one crushes one of these berries a slimy gum sticks to his fingers and this substance causes the small bitter seeds to cling to the beaks of the thrushes, wood-pigeons, black birds and other birds to be later scraped off upon another twig. These seeds are likewise contained in the droppings of birds and thus fall upon branches where they germinate, their roots penetrating the bark and their scions drawing water chiefly from the wood. Mistletoe grows very slowly but lives for a number of years, so that it eventually forms clusters of as much as 4 m. in circumference, which sometimes sprout in an upward direction and sometimes in a downward direction from the branches. It is obliged to anchor itself most securely upon its hairy seat in order to bid defiance to storms. When one splits such an old mistletoe stem together with the branch upon which it is located, one sees to right and left the imbibing roots arranged like the teeth of a comb and surrounded with wood of later growth. Still other roots run lengthwise along the bark; these bear germinating buds from which new mistletoe plants sprout, especially when only the twigs and not the whole branch are removed. This plant is a singular parasite which attacks about fifty kinds of trees in Germany especially those with a soft, juicy bark, like the poplar, the apple tree and the fir, but which injures its victims comparatively little, except when a whole forest is attacked. It is rather to be regarded as a poor beggar struggling hard for existence and making use, even in the winter when other plants are resting, of every bit of light and heat, in order to transform the carbon abstracted from the air by its leaves and green forked twigs, into starch and sugar—in short it fights its way through life as honorably as possible. Its leathery foliage, which poachers employ to lure deer, forms excellent fodder, much craved by goats and cows, whose yield of milk it is said to increase. Whereas the growth and form of the mistletoe are limited by scantiness of space and of food supply, yet, on the other hand, it is true among plants, as well as among mankind, that too luxurious living results in deformities. Among such deformities belongs that

FIG. 4. A WITCHES' BROOM SHAPED LIKE A SMALL TREE. IT WAS FOUND ON A RED FIR

FIG. 5. MESSIANIC TIMBER ROSE ½ METER IN DIAMETER, CAUSED BY IRRITATION OF A PARASITE

FIG. 6. CURIOUS FLATTENING OF TWIGS OF A PINE PRODUCED BY LUXURIOUS LIVING

FIG. 7. GROWTH DUE TO EXCESS OF NUTRITION

FIG. 8. FASCIATED FORMATION OF THE MEADOW CRESS

FIG. 9. SECTION OF ROSE FUNGUS, NURSERY OF LARVAE

peculiar fascination which causes the twigs of a tree to be flattened as in the case of our pine (Fig. 6), or which may even cause the entire plant to take a ribbon-like form. At the same time the leaves and flowers are affected, either distributing themselves normally but irregularly or else crowning the summit in a very compact cluster. Who could recognize in the altered growth shown in Fig. 8 the ordinary meadow cress?

Such a deformity is favored by too rich fertilizing, especially in cases where the lateral twigs have been injured by the scythe or by the nibbling of animals so that the entire current of sap feeds the main shoot. This banding or ribbon-like form is frequently found, however, in cultivated plants and is also inheritable through the seeds as is seen in the case of the pretty garden flower known as the coxcomb, so called from the shape of its flowers. Such plants often grow very irregularly and curve themselves in the form of a sickle or of a bishop's staff, when the flat stem does not, indeed, split into separate bundles through too great a pressure of sap, these bundles rolling themselves up like a snail-shell. The remarkable piling up of tap roots at the base of an annual, which occurs especially in the pine (Fig 7) is also caused by an excess of nutrition. Instead of male blossoms numerous female ones appear, the little taps of which, however, yield fertile seeds. It is likewise true that "well-situated" flowers undergo alterations in a peculiar manner, not only through the fact that the calyx is transformed into flower petals, many of which are further advanced to the rank of stamens, . . . but still more strikingly in a decomposition of the flower into its parts. As a consequence of this the calyx is followed, separated by a large intermediate space, by the petals, then by the stamens in the next higher position, and finally, crowning the whole of the ovary with its pistil. Many garden lovers have probably also been struck by the curious fact that it sometimes happens that from the midst of a fragrant rose the flower axis extends bearing amidst green foliage a second rose, while this second rose, perhaps, is itself crowned by a bud through a similar extension of growth. A rose king! According to the popular notion this is an omen of happiness and sometimes of marriage when it is found in the spring of the year; when it appears in the autumn, however, it signifies misfortune, which, however, may be turned aside according to superstitious belief by plucking the messenger of evil secretly and silently and throwing it backward over one's shoulder. Of quite other origin, however, are the rose apples or "sleep apples," covered with green or red moss, which even today anxious rustic mothers put under the pillows of their little ones with the fond idea that they can thus protect the latter from cramps, or any other disturbance of their slumbers. These so-called "sleep apples" are in reality the nurseries of the tiny rose gall wasp, whose larvae one may find by cutting into such galls—the word gall being a collective name for this sort of formation (Fig. 9). These galls are legion, in fact, since the oak alone is attacked by 150 (more or less) different kinds of gall, each produced by small wasps or gnats. Among the best known of these are the green, red cheeked gall apples and the small lens-like bodies which are often found, even on the same oak leaf as the former, and which in many autumns cover the ground of the forest as thickly as if they had been scattered by the hand of the sower. Thus, the plant furnishes, probably because of the tiny drop of poison which enters its tissues when it is pierced and, perhaps, also, because of the irritation produced by the eggs and the larvae, not only nourishment to the intruders but also a comfortable residence to protect them—one of the most wonderful chapters in the history of nature!

A NEW VEGETABLE IVORY.

A recent number of the French Bulletin of the Colonial Office gives a description of a new form of vegetable ivory, which can be used in European industry in place of the coroso. This new substance is produced by the kernel of an edible fruit growing upon a palm of the upper Senegal-Niger territory, the *Borassus ethiapicum.* The kernel is 7 or 8 cm. long and 5 cm. broad, thus permitting the cutting of balls or plates of considerable size to be used in marquetry, or the making of dominoes, piano keys, buttons, etc. The kernel becomes extremely hard when thoroughly dried as a proof of this it is stated that it is at the present moment being used as building stones for the making of the houses of native chiefs, while it is expected that the future cathedral at Dakar will have tinted pillars constructed of these same kernels.

Efficiency of Aluminum Leaf on Airplane Propellers

Tests Conducted at the Forest Products Laboratory, Madison, Wisconsin

By A. C. Knauss*

WHEN varnishes and oil finishes are applied to furniture or cabinet work, not only are they expected to give it a pleasing appearance and to preserve the grain, but the belief is general that they prevent moisture from entering or leaving the wood. Commercial tests to determine whether varnish is water-proof consist of immersing varnished pieces of wood in water and noting the change in the color of the varnish. Varnishes which do not turn white under such tests are pronounced water-proof. Spar varnishes have shown the least tendency to turn white under such a test.

Experience during the war showed that a water-proof coating was an important factor in keeping airplane propellers serviceable. Propellers not given a water-proof covering changed their moisture content with varying atmospheric conditions and consequently warped, lost balance, went out of track, or changed the sizes of the hub holes so that they would neither fit properly nor give satisfaction when put into service. Linseed oil proved ineffective in preventing these changes, and even after spar varnish was used propellers still went "bad" rapidly and the number of rejections was large. In order to eliminate any factors which might cause changes of shape in propellers, manufacture was subjected to rigid inspection, and close matching of material and conditioning to uniform moisture content was insisted upon more and more.

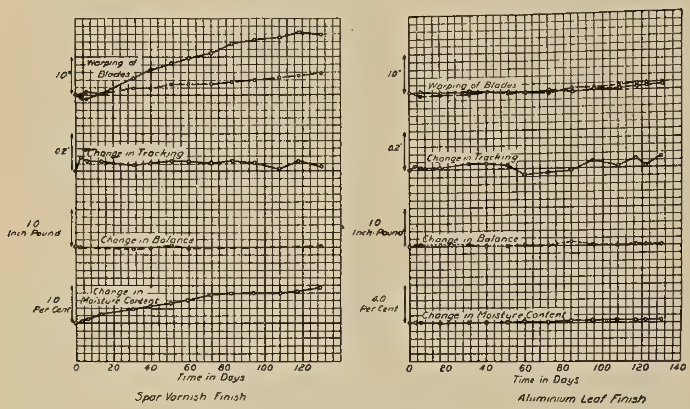


FIG. 1. CURVES SHOWING WARPS OF PROPELLERS PROPELLERS CHANGED FROM 60 PER CENT RELATIVE HUMIDITY TO 90 PER CENT RELATIVE HUMIDITY AT 80° F.

A laboratory for making experimental propellers for the United States Army and Navy and for trying out various propeller coatings was established at the Forest Products Laboratory, Madison, Wis. Many propellers were made up of selected and conditioned material. Others were made of kiln-dried stock on a production schedule. After being carved out, these propellers were given protective coatings of spar varnish or of aluminum leaf. The spar varnish coating was that commercially used for propellers*, while the aluminum leaf was a coating developed at the Forest Products Laboratory. It consists of sheets of beaten aluminum foil, applied to a tacky varnish surface. Enamel or varnish is applied over the leaf to protect it from mechanical wear. After being given these finishes, the propellers were placed in rooms in which the atmosphere was controlled to approximate climatic conditions in war zone sectors. The propellers were weighed and measured at frequent intervals to determine the water-proofing ability of the coatings, and, if the moisture content changed, to determine how seriously the blades would warp or the propeller lose its balance. Over 250 propellers of seven different species of wood have been made and are being given these climatic tests.

In Fig. 1 are shown the results obtained on two propellers which were made under favorable manufacturing conditions but given different finish coatings. The wood, quarter-sawed northern red oak, was carefully kiln-dried, matched for uniform density and conditioned to uniform moisture content before being glued up into propeller blocks. After roughing out, these blocks were stored for a month in a room held under uniform conditions before they were carved out to final shape. During this period conditions within the propeller reached equilibrium and any warping accompanying internal changes would be cut away in the final shaping.

One of these propeller was given a spar varnish finish, the other an aluminum leaf finish. Both were then placed in a room in which the temperature was continually held at 80° F. and the relative humidity at 60 per cent. When the measurements showed that both propellers were remaining unchanged in shape or weight, they were moved to a room in which the relative humidity was held at 90 per cent and the temperature at 80° F.

The propeller covered with spar varnish absorbed moisture rapidly, and the blades warped a corresponding amount. At the end of 30 days it had increased 1.6 per cent in moisture content and one blade had warped enough to cause the rejection of the propeller from service. After having been in the humid atmosphere for 130 days, the moisture content had increased by 4 per cent and one blade had warped 1.6 degrees, four times the error permitted in manufacture, while the other had also warped beyond the prescribed tolerance. The moisture failed to penetrate the covering of aluminum leaf, however, and the second propeller weighed practically the same after 130 days of test as it did at the beginning. Its blade angles remained unchanged, and its tracking and balance were within the limits set for manufacture.

The results on these two propellers were substantiated by the results on all other propellers made under similar conditions. Spar varnish was clearly shown to be an ineffective water-proofing agent, although it retards the absorption of moisture to a great extent.

The same grade of spar varnish finish was applied to practically all airplane propellers made in the United States and sent to France for service, therefore they were as subject to moisture changes as these test propellers. Propellers in service in France normally have a moisture content from 6 to 8 per cent higher than that at which propellers are manufactured in the United States. After reaching France American-made propellers would ultimately increase in moisture content by this amount, and would warp more severely than the varnished test propellers. When moisture changes are prevented, as in the case of the propeller covered with aluminum leaf, practically no warping or change in shape takes place. While the tendency of the wood in the propeller would be to increase from 6 to 8 per cent in moisture content the aluminum leaf would effectively prevent such an absorption of moisture.

These first two propellers had been made of selected material, carefully kiln-dried and conditioned before manufacture, the efficiency of aluminum leaf in making propellers water-proof was further tested on two propellers made under unfavorable conditions. Rejected material, flat-sawed red oak, which was checked because of improper kiln-drying, was glued up, without previous conditioning, into two propeller blocks. After being carved out, both propellers were given

*Assistant Engineer in Forest Products, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture, Madison, Wis.
[1]Standard specifications—U. S. Air Service.

an aluminum leaf finish. Almost immediately this finish was cracked by the checks which were formed in the wood during the process of moisture equalization. After being covered with aluminum leaf, the cracks opened again. The propellers were finally placed in testing rooms, one in a warm, dry room, the other in a warm, moist room. Figures 2 and 3 show the behavior of these propellers during the test. The blades of both propellers changed somewhat during the first days of the test. After approximate equilibrium was reached, however, they remained well within the tolerance throughout the remainder of the 300 days. Both propellers remained within the tolerance for tracking of blades after the internal stresses were equalized, and one propeller remained in balance throughout the test, while the other developed a slight lack of balance.

Since the initial warping of the blades was not accompanied by a change in moisture content it was undoubtedly the result of conditions within the wood which were not allowed to come

in service as in spar varnish finish. While the leaf may soon be worn off when once the propeller is put into service, it will keep the propeller true to shape during transit and storage, thus insuring the flyer a serviceable propeller when it reaches him, while one covered with spar varnish may be twisted enough to be rejected. Furthermore it would be as simple a matter to repair the aluminum leaf coating as the spar varnish. In any event, the life of a propeller in service is usually short compared with the time spent in transit and storage.

As has been shown in the case of the two propellers made of rejected material, aluminum leaf cannot be used to hide unreliable manufacturing methods. Changes in shape are certain to follow such methods. If aluminum leaf were used it would be entirely practical to devise specifications with smaller tolerances and thus secure a better finished product, with the assurance that the propeller would remain within this tolerance for a long time after leaving the factory.

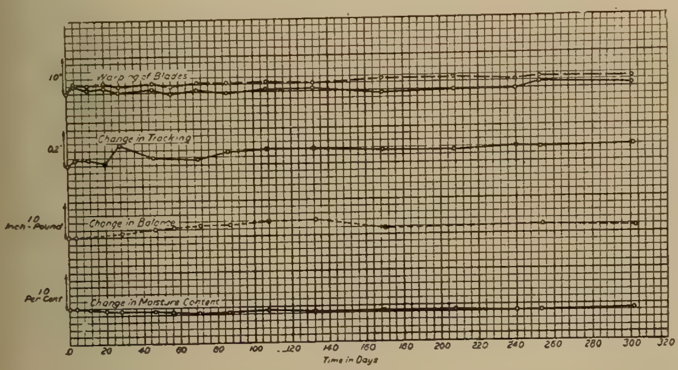


FIG. 2. BEHAVIOR OF PROPELLER WITH ALUMINUM LEAF FINISH SUBJECTED TO 90 PER CENT RELATIVE HUMIDITY AT 80° F.

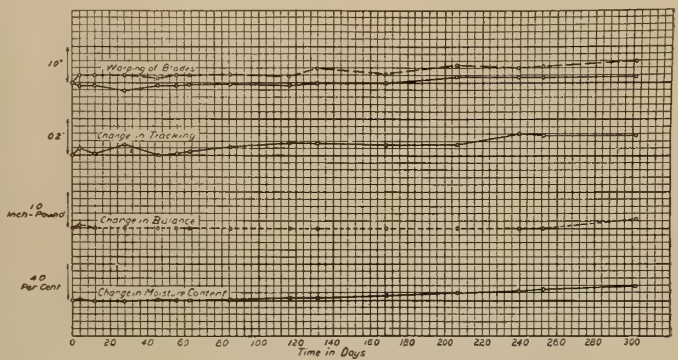


FIG. 3. BEHAVIOR OF PROPELLER WITH ALUMINUM LEAF FINISH SUBJECTED TO 30 PER CENT RELATIVE HUMIDITY AT 80° F.

to equilibrium before the propellers were carved. After approximate equilibrium was reached the propellers remained nearly constant in shape and balance. That the aluminum leaf was effective in preventing the absorption or giving off of moisture by the propellers is shown by the fact that in spite of the cracks the change in moisture content was small. Had the propellers been placed in these rooms without a finish, the difference in moisture content between the two would have reached 9 or 10 per cent. After 300 days of test, however, the total difference in moisture content was only 2 per cent. Had the coating of leaf remained intact, this difference would have been much less.

These two propellers were manufactured under conditions less favorable than would ordinarliy occur in commercial production. Although they warped and changed somewhat, they did not exceed, with one or two exceptions, the manufacturing tolerance.

While spar varnish has been shown by these tests to be rather ineffective as a water-proof covering when applied to propellers, aluminum leaf has shown an extraordinary ability to resist the transmission of moisture, and to protect propellers effectively from external moisture conditions. Even when made under unfavorable conditions and of rejected material, propellers covered with aluminum leaf did not warp enough to become unserviceable when subjected to extreme climatic conditions. Propellers made under favorable conditions and covered with aluminum leaf gave very slight indications of warping or other defects.

The cost of covering propellers with aluminum leaf is no greater than for spar varnish, while the time required can be reduced to two-thirds of that necessary for applying the spar varnish. The weight of leaf is insignificant; less than one-thirtieth of an ounce, costing about fifty cents, entirely covers a propeller.

The aluminum leaf coating is as capable of resisting wear

It can be quite safely said, then, that the aluminum leaf covering is in all respects as good and in most respects much better than spar varnish. Compared with spar varnish, aluminum leaf lasts as long in service, its cost of application is no greater, the time required for finishing is reduced by one-third, and as a water-proofing agent it has shown itself to be immensely superior.

PROPOSED WATERWAY FROM THE ADRIATIC TO THE BLACK SEA

ITALY is seriously concerned over the shortage of coal. The English markets, whence she has heretofore obtained the bulk of her fuel, are partially closed and in this extremity she is forced to look elsewhere for obtaining the equivalent of the 33,000 tons of coal at present required every month for maintaining her industrial activity.

It has therefore been suggested that steps should be taken to utilize the Danube for connecting up the Adriatic with the Black Sea, thus assuring to Italy an adequate supply of liquid fuel from the oil fields of Rumania and those bordering the Black Sea and in the Basin of the Caspian. The so-called Adriatic-Black Sea Line would follow the course of the Danube from the Black Sea to Belgrade, where it would branch off up the Save as far as the confluence of the River Kulpa.

From this latter point, two routes are possible, viz.: by rendering navigable either the upper course of the Save from Sissek to Lubiana, or the Kulpa from Sissek to Venice. A third method of getting over this final section would be by canalizing the Drave from Marburg to Klagenfurt and Villacco, and connecting up the valleys of the Drave and the Upper Tagliamento by a new canal. (Padus, *L'Italia sul Mare*, Nov., 1919. Abstracted through *The Technical Review*.)

"Bumpiness" in Flying*

Effects of Winds and Other Weather Conditions on the Flight of Airplanes

By Charles Brooks and Others

IN a mutual discussion of the meteorological aspects of aviation the aviator and the meteorologist obtain much valuable information. The aviator tells the meteorologist his experiences with various air conditions, and the meteorologist attempts to explain how such conditions are produced, how best to avoid the unfavorable ones, and how to take advantage of the favorable. Furthermore, the information which the aviator can give the meteorologist helps to explain many doubtful weather phenomena which the meteorologist has not been able to observe personally at close range. To obtain facts essential for this paper, about 50 experienced aviators have been consulted. In several cases Signal Corps meteorologists themselves have made flights or have prevailed on others to investigate carefully certain points about which further information was needed.

We have attempted to classify these experiences under the headings: (1) surface winds—effects of local heating, and effects of surface configuration; (2) winds of the free air, turbulent wind boundaries, and flying in clouds and rain; (3) thunderstorms.

SURFACE WINDS—LOCAL CONVECTIONAL CURRENTS.

Experiences of Aviators.—A most common experience of aviators is daytime bumpiness. The bumps in the air may be described in terms of those felt while riding in different kinds of automobiles on roads af varying roughness.

The aviator may be experiencing moderate bumps and suddenly encounter one sharp enough to "throw the fire extinguisher into my lap" or to "set the ship nearly up on end." Then there may be a little more smooth flying until suddenly the support seems to disappear, the propeller appears to give no headway, and down goes the airplane. A bump may announce the bottom, and the aviator slowly climbs again to his proper level. As seen from the ground on a "bumpy" day, the airplane tilts from side to side to a maximum of 30° from the horizontal, and now and then some sharp up or down motion is discernible. The tilts may give the ship a side slip, which will sometimes be sufficient to remove it from one side of a V formation to the other. When such a side slip occurs too near the ground, one of the airplane accidents characteristic of a hot day in the South occurs.

In general, there appear to be differences of opinion among pilots. All say that for ordinary bumps a change of 50 feet is common. A change of 200 feet is experienced at times, and occasionally an aviator comes in with a story of having risen or fallen 500 feet. The larger and faster the airplane the less is the change of altitude due to bumps. Most of the aviators say that unless flying in formation, it is impossible to tell the amount of up or down motion with a bump or in a "hole" without watching the altimeter.

Most bumps in the air occur near the ground and on bright, hot days. In the northeastern United States, 3,000 to 5,000 feet is the upper limit of bumpiness on a summer day, though in very hot weather, bumpiness, sometimes extreme, occurs at elevations even above 8,000 feet. In Texas the air is bumpy sometimes to more than 10,000 feet. In winter the usual limit of bumpiness at Ellington Field, Texas, is 1,500 to 2,000 feet. Ordinarily, however, the extremely bumpy conditions are within 500 to 2,500 feet of the ground or just under and about cumulus clouds.

The places where bumps occur are well known to aviators. Roads, railroads, edges of plowed fields, forest edges and clearings, barn roofs, hangars, ditches, borders of swamps, shore lines, all give bumps, the sources of which can be identified generally to 700 or 800 feet, and on calm days occasionally to 2,500 and even 3,500 or more feet. The bumps associated with macadam roads and other hot places are not necessarily directly over the road, but to leeward at a distance depending on the velocity of the wind and the height of the airplane. Some aviators at Rich Field allowed for fall of about 15 feet in crossing a sunken road in the vicinity of the field. Railroads have the same effects as roads. Creeks seem to have down currents over them.

As to conditions along the coast, the following statement by Donald B. Kimball, a naval aviator, shows the effect of difference in convection over water and land surfaces:

"The air over the shore line of islands or protruding necks is especially treacherous on hot days, for violent bumps may catch the pilot unawares after navigating through the smooth air over the ocean [especially in such places where the water is rather cold relative to the beach, as at San Diego, Cal. The shore-line bumps of Chesapeake Bay, and the Gulf of Mexico may be scarcely noticeable in late summer.] As a rule, the depth of these bumps extends noticeably to about 1,500 feet, very rarely above 2,000 feet, the violence varying indirectly with altitude. These conditions are somewhat altered if cumulus clouds tend to form. The region just under and within the clouds is probably bumpiest of all and there appears to be a sharp decline in violence on climbing above the clouds. On a clear, hot day it is not an uncommon feat for a perfectly balanced machine to fly several minutes at altitudes under 1,000 feet without having the foot controls moved. On such a day I once even saw a pilot step from the front seat to the wing and thence to the rear seat at an altitude of about 75 feet. Such a feat would be almost suicidal in land flying on a hot day."

Explanation of Bumpiness.—The local vertical currents which occur on warm days are the result of the unequal heating of the lower air. The air next to the ground gets hot; and, therefore, expands. Over a bare, dry field the heating is greatest. Thus, the surface air locally may become considerably lighter than the cooler air at the same level or even above; and so at the first opportunity some of this heavier air moves laterally or comes down and forces some of the lighter air to rise. On a quiet day at the earth's surface the movement of this cooler air is marked by light, variable winds interspersed with calms. The process of displacement is intermittent. When there is a wind blowing, the occasions when the cooler air moves toward the warmer places are marked by gusts or slack wind. These gusts are the result not only of the combined strength of the horizontal components of convectional winds and of the general wind, but also of the quick, down movement of air, which has a higher velocity than the friction-limited wind next to the ground.

The reason for the bumpier conditions in the middle of the day and for the greater bumpiness in Texas than elsewhere is now apparent—the hotter the lower air relative to that above, the stronger are the convectional currents and the gustier the wind. The reason for the decrease in bumpiness aloft is that near the earth there are likely to be the steepest temperature and wind velocity gradients. Again, the upper limit of bumpiness is the upper limit of the convectional columns of detached masses of rising air; and in much of Texas, at least, the tops of the convectional upcurrents are marked almost daily by the tops of cumulus clouds. (Cf. Figs. 1 and 2.) The locations of bumps over roads, railroads, plowed fields, open spots in woods, etc., depend on the differences in the degree of heating of different parts

*Abstracted from the *Monthly Weather Review.*

of the landscape. The road gets hotter than the fields on either side, and so the air from both sides flows toward, and displaces upward, the air over the road. (A, Fig 1.) Plowed fields are likewise hotter than the surrounding fields, because their dark, loose surfaces absorb so much more heat, and conduct downward so much less heat, than the surfaces of unplowed fields. Open woods favor bumpiness because some parts become hotter than others. (B, Fig. 1.)

Isolated hills, especially short or conical ones, should be avoided during warm, still days, for on such occasions their sides are certain to be warmer than the adjacent atmosphere

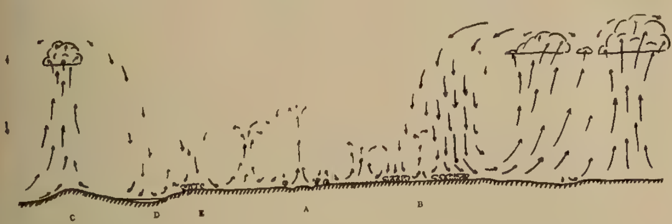


FIG. 1. LOCAL CONVECTIONAL CURRENTS ON CALM DAY.

at the same level and hence to act like so many chimneys in producing updrafts. (C, Fig. 1.)

The rising currents are interesting, not only because of the way in which they disturb airplanes, but also because they may be utilized by aviators who are trying to make altitude in the shortest time. Many use a rising air column that forms the cumulus, but they claim that many accidents have occurred because of the uncertainties of its direction and action. An aviator who has flown over an active forest fire never does so again, if possible.

Down currents, marking the movement of relatively cool air over ponds (D), lakes, and clumps of trees (E, Fig. 1), do not have the marked velocity of upward currents, but are more dangerous. Their boundaries may be sharp enough for an airplane to fly with one wing in and one wing out of the descending current.

EFFECT OF TOPOGRAPHY ON WINDS.

The effects of heating and cooling of the earth's surface upon the flow of air is not the only cause of turbulence, for there is the effect of topography, which introduces phenomena quite as dangerous and distressing to the airman as convection.

Aviators' Experiences.—Roughnesses (including trees and buildings) of the surface produce eddy motion, which in a moderate wind will reach to 1,000 or 2,000 feet and in a strong wind to 3,000 feet or more.

During a gale the edge of the woods near Houston, Texas, is marked to a height of 1,000 or more feet. Bad bumps have been felt 2,500 feet above and to leeward of hangars on a windy day.

Neumen reports that on days with high winds in eastern Maryland "the air [up to 10,000 feet] seems to be moving in great horizontal eddies or rolls similar to the rolling of ocean waves. The air plane rocks just like a rowboat in the sea."

Many pilots have been questioned regarding the effect of topography upon the action of their planes at various altitudes. In addition to the natural configurations of the ground, there are also the effect introduced by buildings. groves of trees, and other obstacles over which the wind must pass. The general opinion is that these effects do not extend upward nearly so far as strong convection does, except, perhaps, in very rough mountainous country or with winds of gale force. It appears also that the altitude to which such disturbances may extend is proportional in general to the wind velocity and the size of the surface irregularities.

Lieutenant S. W. Addison says when passing over buildings, groves of trees, or similar obstacles bumps are generally experienced, their extent being influenced mainly by the strength of the wind. As obstacles of this character are approached with a following wind the machine will lift and drop with equal suddenness on the other side. If approached head to wind the converse will take place—the machine will probably drop, sometimes nearly to the ground, just before reaching the obstacle, and rise as it leaves it. This seems to be due to the fact that when the wind strikes the obstacle it shoots upward. (Fig. 2.) It would be difficult to say what height this updraft generally reaches, but the writer's experience is that it goes up well above the actual height of the obstacle, and is "flattened out" on the other side, where there is often an unmistakable down current.

The turbulence caused by hills or mountains depends largely on the local topography and on the winds concerned. Point Loma, near San Diego, Cal., gives birth to marked turbulent conditions over and to leeward of it.

An aviator flying at 3,500 to 4,000 feet inland from San Diego with the wind, passed over some mountains 2,000 feet high. On the lee side he was forced down, or fell, 1,500 feet. The prevailing cloud sheet at 4,000 feet gave from below no notable indication of such a current, but it seems probable that the upper surface would have shown where the wind was up and where down. The upper surface of this "velo" (stratus) cloud sheet is usually uneven; but this aviator on other occasions had not happened to find how to tell from the form of the cloud surface the underlying topography.

The air over a mountain region is usually turbulent. Capt. F. N. Bartlett, in a flight from Scott Field, Ill., to Kelly Field, Tex., a year ago had nine hours of difficult flying over the Ozarks between Eberts Field, Ark., and Post Field, Okla. This turbulence attendant upon flying over the Ozarks was strongly manifest in a recent balloon trip from Fort Omaha, in which it was desired to maintain a constant elevation of 5,000 feet above sea level. This was found absolutely impossible and the balloon often was dragged down to within a short distance of the ground, or caused to ascend again, almost out of the control of the pilot. The accompanying balloon at 10,000 feet was but little affected. On windy days over

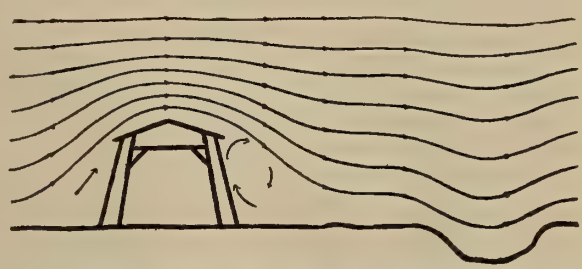


FIG. 2. EFFECT OF MINOR SURFACE IRREGULARITIES ON LINES OF WIND FLOW IN A LIGHT WIND. (FROM LINKE.)

rough topography, bumpiness has been generally observed to 4,000 feet.

Lieut. R. O. Searles, the flight commander of the De Haviland squadron, which made the trip from Ellington field to the Pacific coast and back, related that on the 24th and 26th of February, 1919, it was not possible to enter the Grand Canyon with a plane, but that it was easily possible on the 25th. Sergt. E. B. Scott indicates this was doubtless due to the pressure distribution on those dates, for on the 25th the gradient wind was not of great speed and, moreover, conformed with the direction of the canyon, whereas on the preceding and following days the pressure gradient was steeper and the wind direction was such as to produce great turbulence in passing across the canyon. It has been reported that in a strong south wind the back-and-up current of the eddy in the lee o fthe south wall of the canyon has carried tin cans up the cliff and into the yard of the hotel.

Interpretations.—Wind Eddies.—"Just as eddies and whirls exist in every stream of water, from tiny rills to the great rivers and even the ocean currents, wherever the banks are

such as greatly to change the direction of flow, and wherever there is a pocket of considerable depth and extent on either side, and as similar eddies but with horizontal instead of vertical axes occur at the bottom of streams where they flow over ledges that produce abrupt changes in the levels of their beds, so too, and for the same general reasons, horizontal eddies occur in the atmosphere with rotation proportional, roughly to the strength of the wind. These are most pronounced on the lee sides of cuts, cliffs, and steep mountains; but also occur, to a less extent, on the windward sides of and above large obstructions."[1]

"The inertia of the wind crossing the mountains tends to carry it on well above the valley or plain beyond, but its drag on the yower air, due to viscosity, deflects it downward. (Fig. 3.) Because of this deflection a foehn wind often strikes the lower slopes with great violence, from which, and mainly because of its dynamical heating, it rebounds to higher levels. Along a belt, therefore, well down the mountain, or even slightly beyond its base, the surface wind may be exceedingly turbulent and violent, while both farther away and also on the higher slopes it is comparatively light. Furthermore, owing to changes in the general direction of the crossing current, or in its strength, or both, the wind belt may shift up or down the mountain or even vanish entirely."—*W. J. Humphreys.*

"The air at the top and bottom of wind whirls is moving in diametrically opposite directions—at the top with the parent or prevailing wind, at the bottom against it—and since they are close to the earth they may, therefore, be a source of decided danger to aviators. There may be some danger also at the forward side of the eddy where the downward motion is greatest.

"When the wind is blowing strongly landings should not be made, if at all avoidable, on the lee side of and close to steep mountains, hills, bluffs, or even large buildings, for these are the favorable haunts, as just explained, of treacherous vortices. The whirl is best avoided by landing in an open place some distance from bluffs and large obstructions, or, if the obstruction is a hill, on top of the hill itself. If, however, a landing to one side is necessary, and the aviator has a choice of sides, other things equal, he should take the *windward* and not the *lee* side. Finally, if a landing close to the lee side is compulsory, he should if possible head up the hill with *sufficient velocity* to offset any probable loss of support due to an eddy current in the same direction. He could, of course, avoid loss of velocity with reference to the air, and therefore loss of support, by heading along the hill, that is, along the axis of the vortex, but this gain would be at the expense of the dangers incident to landing in a side or cross wind. His only other alternative, heading down the hill, might be correct so far as the direction of the surface wind is concerned, but it probably would entail a long run on the ground and its consequent dangers.

"Eddies of a very different type, relatively small and so turbulent as to have no well-defined axis of rotation, are formed, as is well known, by the flow of strong winds past the side or corner of a building, steep cliff, and the like. In reality such disturbances are, perhaps, more of the 'breaker' type, presently to be explained, than like a smoothly flowing vortex, and should be avoided whenever the wind is above a light breeze.

"Clearly, the support to an airplane flying either with or against a wind of this kind is correspondingly erratic, and may vary between such wide limits that the aviator will find himself in a veritable nest of 'holes' out of which it is difficult to rise, at least with a slow machine, and sometimes dangerous to try. However, as the turmoil due to the horizontal winds rapidly decreases with increase in elevation, and as the aviator's safety depends upon steady conditions, or upon the velocity of his machine with reference to the atmosphere and not with reference to the ground, it is obvious that the windier it is, the higher, in general, the minimum level at which he should fly."[1]

[1]Humphreys, W. J. "Winds Adverse to Aviation," etc., manuscript enlarged from paper published as Chapter IV, in a Manual of Aerography for the United States Navy, 1918.

Effect of gusts.—Aside from the obvious effects of vertical currents, already discussed, the mere changes of velocity in a horizontal direction that accompany the passage of gusts tend to produce an up-and-down motion in an airplane flying with or against the wind. If the airplane is flying with the wind, any increase in the velocity of the wind will momentarily reduce the support of the airplane, thereby causing it to drop, while any decrease in velocity will momentarily increase the air speed of the machine, tending to make it rise. The reverse is the case if the machine is going against the wind.

This is because in a steady wind an airplane itself moves as if in a calm. Thus if the wind is unsteady the number of gusts encountered in a given time will be the same whether

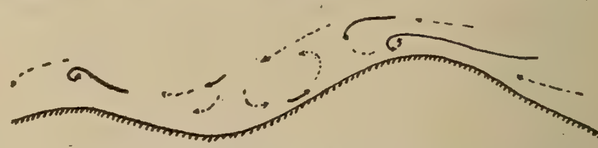


FIG. 3. WIND CROSSING A RIDGE. (FROM CLOUD MOVEMENTS OBSERVED ALONG THE HUDSON RIVER, AUGUST 4, 1918.)

there is a following or a head wind. And if, as the anemometers indicate, gusts have no more abrupt onset than end, the effect of a gust from in front or of a lull from behind should be the same. Nevertheless, aviators say they can feel the difference between a head wind and a following one, and that they climb fastest against the wind. Soaring birds have the same experience. This would seem difficult to explain in any other way than that gusts begin more suddenly than they end. Apparently, we need more refined observation to show what the difference is.[2]

Effect of gustiness on a turning airplane.—Probably the chief disturbance due to gusty wind—excessive tipping and side slipping—occurs not during straightaway flying but as the aviator turns at low levels from flying against the gusts to flying with them.

WINDS OF THE FREE AIR: TURBULENT WIND BOUNDARIES.

The difficulties of the pilot do not cease once he has risen above the turbulence of the lower air produced either by local convectional currents or by the tumbling of the wind over the surface of the earth. There are numerous accounts by aviators which tell of wind boundaries which are entirely invisible.

"Ordinarily there is not more than 100 feet of turbulence on wind boundaries. The boundary separating two winds is easily noted by the great disturbance, and bumpiness, the violence of which depends on the velocity of the winds. In many instances the change of winds will be just above where the cloud layer is forming or slightly above the haze."—*E. M. Powers.*

"*Wind layers.*—For one reason or another it often happens that adjacent layers of air differ abruptly from each other in temperature, humidity, and density, and therefore, as explained by Helmholtz, may and often do glide over each other in much the same manner that air flows over water, and with the same general wave-producing effect. These air waves are seen only when the humidity at the interface is such that the slight difference in temperature between the crests and the troughs is sufficient to keep the one cloud capped and the other free from condensation. In short, the humidity condition must be just right. Clearly, then, though such clouds often occur in beautiful parallel rows, adjacent wind strata of different velocities and their consequent air billows must be of far more frequent occurrence.

[2]Abstract from C. C. Turner, *Aeron. Journ.* (London) 22: 285-6, 1918.

"This fact is abundantly proved by all types of aerological work, as well as by all those who ascend into the air. Kite balloons in ascending are often seen to rotate, pointing their noses in various directions, indicative of various wind directions at different levels, yet there may be no cloud layer at the interface to mark it. Free balloonists make use of these layers of air, which may have different directions and speeds in order to aid them in achieving whatever result they seek, such as distance or a given destination."[1]

"*Wind billows.*—When one layer of air runs over another of different density billows are set up between them, as is often shown by windrow clouds. However, the warning clouds are comparatively seldom present, and therefore even the cautious aviator may, with no evidence of danger before him, take the very level of the air billows themselves, and before getting safely above or below them encounter one or more sudden changes in wind direction and velocity due, in part, to the eddy-like or rolling motion within the waves, with chances in each case of being deprived of a portion of the requisite sustaining force. There may be perfect safety in either layer, but, unless headed just right, there necessarily is some risk in going from one to the other. Hence, flying at the billow level, since it would necessitate frequent transitions of this nature, should be avoided.

"When the billows are within 300 meters (1,000 ft.), say, of the earth (often the case during winter owing to the prevalence then of cold surface air with warmer air above) they are apt to be very turbulent, just as, and for much the same reason, that, waves in shallow water are turbulent. For this reason, presumably, winter flying sometimes is surprisingly rough. Fortunately, however, it is easy to determine by the aid of a suitable station barograph whether or not billows are prevalent in the low atmosphere since they produce frequent (5 to 12 per hour roughly) pressure changes, usually of 0.1 mm. to 0.3 mm. at the surface."[1]

CLOUDS AND RAIN.

Flying in clouds or above them is the choice of the aviator over enemy territory more than over friendly country. How the aviator in the United States feels toward the clouds is well shown by the classification of the weather conditions under which the postal aviators between Washington and New York have to fly. In succession these are—ideal, fair, occasional clouds, frequent clouds, high winds, thick clouds, thick clouds and high winds, rain storms, combination of storms and heavy fogs. Clouds are generally avoided because one cannot see where he is going nor keep right side up. Cumulus clouds, particularly those with hard-looking outlines, are avoided because of their bumpiness, coldness and fogginess; also, not infrequently because they have falling rain. Such clouds are usually roughest and wettest at their bases. A full account of "Danger in flying through clouds," by Capt. B. C. Huchs, was presented to the Aeronautical Society of Great Britain, and reprinted in Scientific American Supplement, June 15, 1918, page 375.

Strato-cumulus clouds and cumulus clouds with fuzzy edges have weaker ascensional currents and are less bumpy to fly through. Aviators in flying about such cumulus clouds can easily lop off corners and even make small clouds evaporate by flying through them. Some cumuli have cavities 1,000 feet high in their bases.

Flying in the rain is avoided, if possible. Even in midsummer in Texas, at 7,000 feet in the air, an aviator flying through a rain cloud felt so cold that he described the rain drops as "ice particles." The impact of rain drops is sufficient to make them feel solid. On this occasion, there was a considerable collection of water on the airplane. The weight of rain water can hardly affect the performance of the airplane much, unless the drops freeze on. In the spring of 1918 an aviator in Texas had such an experience during a shower; he flew up into a cloud until at 7,000 feet his airplane had become so covered with ice that he could go no higher. The effect of rain on the propellor is destructive. The p[...] moves at such a high velocity that unless specially p[...] the rain drops cut it as if they were bullets.

Aside from the general unpleasantness of flying in r[...] water may cause faulty engine action by getting [...] carburetor and the ignition system. As to general tu[...] within clouds, there is very little definite informat[...] aviators because the propeller so violently churns u[...] in the neighborhood, and this mixing is often suf[...] mask any real small-scale turbulence that may exist [...]

THUNDERSTORMS.

In thunderstorms, however, these turbulent cond[...] of considerably greater magnitude, and are, in fact, so violent that great danger is entailed in flying in or about them. Indeed, few aviators have flown into a thunderstorm and come out alive.

Experiences.—Lightning is one danger. About August 1, 1918, an aviator flew into a thunderstorm at Paxton, Ill., and was found dead, with lightning burns on his body. Another aviator a year earlier, thinking apparently that the thunder storm was going with the lower wind flew into the storm and was killed. Several years ago a flyer named Ehrmann had his machine set on fire by lightning, but he escaped unhurt.[3]

Capt. Cave says:[4] "It is possible that danger from lightning to an airplane flying through a thunderstorm may be no more than that incurred by a pedestrian walking across an open common during a storm. A pilot who was flying above a thunderstorm last summer reported that long sparks were given off by his machine at intervals. It is very likely that this happened every time there was a flash of lightning from the cloud below him."

Aviators in the United States have also experienced such discharges while flying in thunderstorms or through gaps between thunderheads.

The *turbulence* within a thunderstorm is awful to experience.

"A French machine was called upon to ascend during a violent thunder and windstorm for important observation work over the German lines. When at a height of several thousand feet the members of the squadron below saw the turret and its machine gun stripped from the craft by the gale.

"The observer's seat was next to go, but the occupant, grasping the wing stays, clung to the sailing plane. The craft was whipped about in the sky at will and the cloth completely stripped from the fuselage. Both pilot and observer were clinging to their broken craft when it reached the earth after a series of gyrations rivaling the most daring acrobatics practiced by the Allied aces. Both occupants escaped serious injury."[5]

It is quite likely that in such cases pilots and observers think very little of thunderstorm structure or the meteorological aspects of the situation.

Many aviators have experienced the great up-current which occurs on the front of the squall wind issuing from the base of a thunderstorm. Ascents of several thousand feet have been reported not only in Texas but also in Florida. Two of the most striking ones, both from Texas, will be cited. On one occasion, near Fort Worth, the aviators began to return to Carruthers Field on the approach of a thunderstorm. Lieut. Morgan on banking for a turn while just over the squall front was suddenly lifted from 2,000 to an elevation of 7,000 feet, a rise of 5,000 feet in almost no time. He thought that his altimeter had "gone crazy." On descending immediately he reached the field just before the squall struck it. Other aviators were lifted similarly by 2,000 to 4,000 feet. Those that landed after the "50-mile" squall began had to land with their propellers going full speed.

[3] C. C. Turner, "The Romance of Aeronautics," page 229, Philadelphia, 1912.

[4] Cave, C. P. J. Some meteorological conditions which increase the danger of flying *Aero. Jour.* (London), 1917, vol. 21, p. 301.

[5] W. S. Forrest, New York *Tribune* report, July 14, 1918.

In the other instance, Lieut. Cobb was "stunting" near Love Field at about 3,500 feet altitude during the approach of a thunderstorm. After doing three evolutions, taking about 15 minutes, he found that he had gained some 3,500 feet in altitude, instead of losing 1,500 feet, as was usual. Sometimes the lifting would be of the order of 500 feet in a minute. This indicates that there was a wind with an average vertical component upward at about 5 miles per hour (2 m/s) blowing toward the storm, an upward rate quite to be expected under such circumstances. At the end, the aviators noticed sharp mammato-cumulus above and strato-cumulus clouds below them. They seemed to be at an altitude about midway between them, though they were some 5 miles away from the

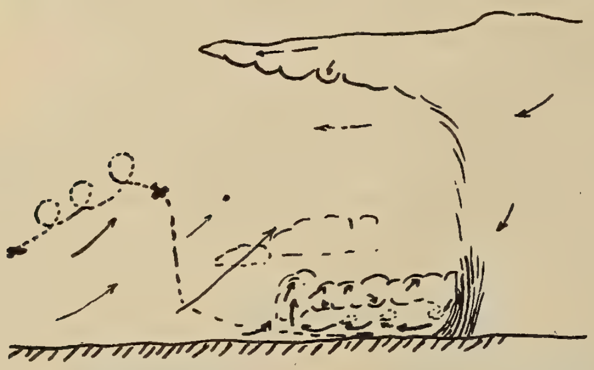


FIG. 4. WINDS EXPERIENCED ON THUNDERSTORM FRONT NEAR LOVE FIELD, TEX., FROM DESCRIPTION BY LIEUT. COBB

storm front. On descending they soon entered extremely bumpy air and were able to land only by diving into the wind with the engine on (Fig. 4). The rain began immediately after that. Landing in thunder squalls presents considerable difficulty. Once an aviator above such a squall, in the opposite return current, headed into the wind and made a descent to the field. He did not observe that the surface wind was opposite in direction. As he approached the landing place he noticed that for some reason he was not losing speed, and when only 5 feet from the ground saw that he was going with the wind. He was moving so fast that he went 4 miles before getting sufficient elevation to turn and come back.

Interpretations.—The air movements about thunderstorms, in the lower level at least, seem to be relatively simple. The heavy fall of rain and the coolness of the air under a thunderstorm produce a down-flow of air which spreads laterally in the form of a squall. The squall wind is stronger than the forward rate of advance, and so there is a considerable rate of ascent on the front; and the cold squall wedge also forces up the warm general wind. The air which goes down from a thunderstorm is supplied by a return flow of low velocity above the squall. (Fig. 4.) This return takes place above 1,000 or 2,000 feet and is probably strongest at 3,000 feet or higher. In the front of the squall the presence of obstructions will locally increase the rate of ascent of the air, especially when such obstructions are in the lee of a flat area. The extraordinary up-current near Fort Worth, referred to above, occurred just in the lee of Lake Worth. An airplane in the rain under the thunderstorm is likely to be carried down not only by the weight of the rain but also by the downflow of the air. An airplane in the squall itself is likely to be disturbed by eddies. An aviator who wants to go around a thunderstorm will find the fastest going at a height of about 2,000 feet, between the outflowing wind below and the inflowing one above.

AIR DENSITY CHANGES AS AFFECTING SUPPORT.

On cold days with high atmospheric pressure an airplane has little difficulty in "taking off." For example, Capt. H. H. Storrer cites an instance when with the barometer at 30.67 inches and the temperature 30° F. "one could ascend at a fair rate with the elevators in the position usually employed in horizontal flights; this, of course, in calm air."

On hot days or at altitudes of a few thousand feet, on the contrary, the rarefied air often makes it difficult to rise from the ground. Aviators at Kelly Field, Tex., and Fort Sill, Okla., have noticed repeatedly that on very hot days there was difficulty in taking off, due to the rarefied air. More striking than this, however, is the case of failure of the propeller to "take hold" in the rare air of higher elevations. Lieut. Nutt, of Ellington Field, Tex., accustomed to the distance required to take off in low elevations, failed to take into account the fact that a greater distance would be required at a higher elevation, and at Denver, Colo., October, 1918, crashed into a fence in consequence.

Not only are these difficulties noticed in taking off, but also are they troublesome in landing, for the plane continues to roll along the ground for an unusual distance before coming to a stop. Landing fields at relatively high elevations should be larger than those near sea level and also at their edges should be free from obstructions like telephone and power lines, which might be permitted at lower levels.

CONCLUSION.

From the accounts of the numerous exciting experiences aviators have because of the conditions of the air, it is obvious that the more meteorology an aviator knows the better he can handle himself in the air, other things being equal. Furthermore, it is evident that the airplane has opened to the professional meteorologist a new and potent means of investigating the phenomena of the air. Much can be surmised from careful observations of cloud movements taken from the ground; but how much more satisfactory it is to be able to fly up and investigate personally, what is happening!

The *Weather Bureau* would be glad to receive accounts of unusual flying experiences ascribable to weather or air conditions.

TAUTOMETER FOR TESTING DOPED SURFACES.*

THE power of tautening varies with different dopes; hence the necessity for the tautometer, which should measure the degree of tautness brought about by the particular dope or covering employed. Until recently the tautness was simply more or less guessed, the method usually adopted being to merely tap the doped fabric and deduce the tautness from the note produced. The higher the note, the greater the tautening power of the dope was assumed to be.

The function of a tautometer is to measure the effect of a depressing force, usually exerted by applying a known weight to the center of a known area of doped fabric. This tautness determination is a measurement of at least two important factors of the dope, *i. e.*, the tension of state of strain given to the doped fabric and the flexibility of the dope film.

The method of tapping has proved to be both inaccurate and misleading. For instance, a hard film is frequently obtained when an acetyl dope is employed and the doped fabric sounds tauter than measurement with a reliable tautometer proves it to be. In reality a high note frequently indicates a hard and brittle film which will have a great tendency to crack on exposure.

There are various types of instruments for measuring tautness now in use; one, for example, consists of a heavy round-bottomed framework, having a pivot through the center attached to a spring on the upper side, which, in turn, is connected with a pointer. Except for a knob fixed to the lower end of the pivot, only the outer rim of the round bottom of the instrument touches the doped fabric. This instrument is placed on the frame to be measured, and according to the tautness of the doped fabric the knob at the end of the pivot is pushed upward to a greater or less extent, thus

*From *The Jour. of the Soc. of Automot. Eng.*

compressing the spring and moving the pointer to a position which may be read off on a circular scale. This instrument has many disadvantages, the chief of which is that the tautness of only the small portion of the doped fabric enclosed by the rim of the instrument is measured. Also, the whole weight of the tautometer rests on the doped fabric, and that is obviously no small factor in its disfavor.

The tautometer shown is based on the principle of a balance with a 10 to 1 beam or any other convenient ratio, so that the deflection of the long arm *a* can be magnified for a slight depression of the other *b*. The beam is suspended on a knife-edge in the ordinary way, except that the support is connected with a screw *c* which is used to adjust the beam to any height required. This screw also serves to fix the whole apparatus to a framework *d* which fits over the frame to be measured in such a way that the specified weight, 400 g. having been adopted in the case of the instrument described, is suspended from the short arm, exactly over the center of the frame. This weight is compensated by a 40-g. weight *e* in the scale pan, suspended from the long arm *a*.

When this tautometer is placed on a frame the reading of the pointer at the end of the long run should be at zero on the curved scale *g*, attached to the framework at the right side. If this is not the case the necessary adjustment can be effected by turning the screw *c* in the direction required either to raise or lower the beam. When this has been done the 40-g. weight should be removed from the scale pan. This causes the 400-g. weight *g*, which till now has been just touching the surface, to rest on the doped fabric, and the depdession due to it can be read off by the pointer and scale at the other side. This curved scale can conveniently be divided into graduations representing millimeter or fractional parts of an inch depressions of the 400-g. weight on the doped fabric.

The 10 to 1 beam has the advantage of causing a perceptible deflection of the pointer for only 1-mm. depression of the weight, and it must be understood that the smallest deflections are caused by the tautest frames.

A simple adaptation on the same principle has also been used for much larger frames and might with advantage be employed for airplane wings. In this case all framework is dispensed with, except for the bracket used in supporting the knife-edge *a* of the beam *b*. This is

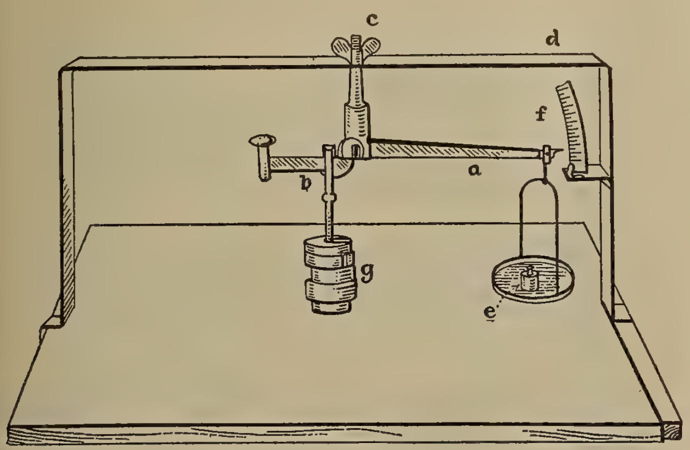


FIG. 1. A TAUTOMETER FOR TESTING SMALL PORTIONS OF A DOPED SURFACE, WHICH EMPLOYS THE PRINCIPLE OF A BALANCE WITH A RATIO OF LEVERS THAT PROVIDES FOR A MAGNIFICATION OF ANY DEPRESSION OF THE SHORT ARM

fixed to the wall at a convenient height and should stand out half-way across the frame *c* of the wing to be measured, so that the weight to be used for determining the tautness can be arranged to touch the center of the frame. The beam itself should be counterpoised, as before, so as to give a long arm and a short one, when in equilibrium on the knife-edge. Then, as in the previous case, a heavy load is suspended from the short arm to test the tautness of the doped fabric, but instead of having the compensating weight in a scale pan, a sliding weight *d* has been adopted, which is placed directly on the beam. When a reading is taken, the weight is slid from the marked position of equilibrium *e* to another one *f* nearer the knife edge, so calculated

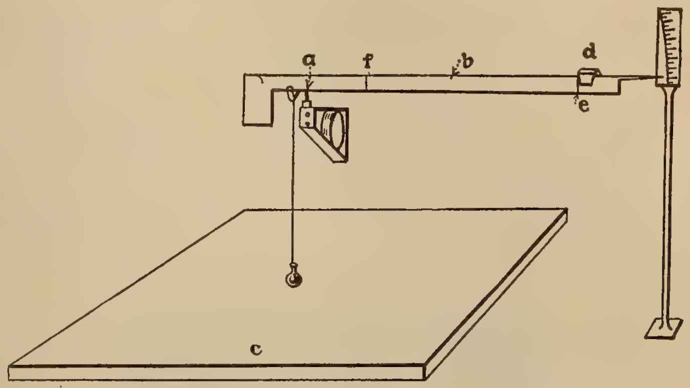


FIG. 2. AN ADAPTATION OF THE SAME PRINCIPLE THAT IS CAPABLE OF USE IN THE TESTING OF LARGE FRAMES AND AIRPLANE WINGS

as to allow the necessary load to rest on the doped fabric. The reading of the pointer on the curved scale can then be noted as before, to show the depression of the doped fabric caused by the weight of the load.

RECOVERY OF NITRE AND PITCH FROM "SMOKE CANDLES."

E. R. THOMAS.

AMONG the various duties of an ammunition officer in the field is that of the disposal of dangerous and unserviceable ammunition.

Those stores such as "ground flares" (consisting of shellac and nitrates) and "smoke candles" (pitch and potassium nitrate) which depend for their efficiency on the dryness of the priming composition used for their ignition, are particularly liable to deterioration on exposure.

The author was horrified to find that the unserviceable flares and smoke candles were being burnt or dumped in the English Channel with a considerable expenditure of time and labor. Although he had been advised to conceal his knowledge of chemistry—advice not without its point—he set out to find some simple method for recovery of the pitch and potassium nitrate from the smoke candles. This was soon elaborated, and with the aid of a band of Chinese coolies, over a ton of pitch and nearly a ton of potassium nintrate were produced daily.

The methods were crude. The extraction was done in Soyer stover, and the crystallization in unserviceable cartridge cylinders. The stirrer was part of a broken ammunition box, and the fuel was waste wood from the same source. After all expenses were met, the work resulted in a profit of at least £20 a day.

The pitch was mixed with sand and used as a substitute for timber for flooring purposes. The work was also carried out at two convalescent camps where the labor cost was nil. In both places large "physical training huts" were completely floored with material from the recovered pitch. The potassium nitrate was stored and ultimately returned to England.

The success of these operations led to their authorization and extension to many classes of unserviceable ammunition previously dumped in the Channel.—Abstracted by the *Journal of the Society of Chemical Industry* from a paper read before the British Association for the Advancement of Science, September, 1919.

The Great Problem of Landing*

Its Bearing on the Future of Aviation

OF the many problems asking for the ingenuity of flight enthusiasts the landing problem is in all ways the biggest, because it is a subject for invention, and because it carries with it the complete future of aviation. Wild opinions are being given regarding air brakes, extended surfaces, extraordinary speed variations, etc., etc., but the fact that you must land and start appears to be lost sight of.

Flying is easy—dead easy—and any fool can manage a machine in the air; but to start a real high-speed machine and to land it is a problem exceeding the wit of the thing called man at the present time.

A FLYING MACHINE OF THE FUTURE

Look at so-called facts. Flight is possible, according to the scientific experts, up to the speed of sound, say, roughly, up to 1,000 miles per hour. The present ratio between flight and landing speed is about 3 to 1—*i. e.*, you can fly at 150 m.p.h. and land at 50. In other words, looking at the future, you can fly at 1,000 m.p.h. and land at 330 m.p.h. *It can't be done.*

Is any improvement on this ratio possible? Well, say there is, and give the improvement as 25 per cent, making the landing speed 250 m.p.h. You still can't do it, or even look at it. If air brakes will improve it by 10 per cent and extended surfaces by 10 per cent, you are still faced with a landing speed of some 250 m.p.h.!

What is the alternative? Several may be suggested, but none can be put as tried. To make an efficient flying machine the landing gear must be omitted—that goes without saying. The landing gear in a modern machine amounts to some 10 per cent of the total head resistance, and *this ratio will increase.* It follows, arguing from first principles, that both landing and starting must be done by means outside and separate from the machine itself.

The starting should not be too extraordinary. Armstrong-Whitworth's, of Newcastle, made a good catapult years ago, and I have seen this throw a 2-ton machine into a speed of 60 m.p.h. at a length of 60 feet. There is no great snag here. You can start the machine. But the stopping is different, and it takes a wise man to lay down rules for it. The obvious, the entirely simple solution, is a wind tunnel, wherein the wind speed equals the flying speed of the machine. That is obvious; but the expense of this scheme is equally obvious.

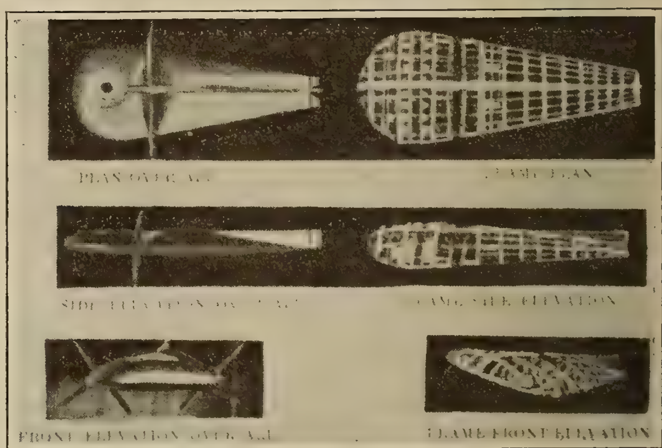
Assume a machine weighing 1,200 tons, flying at 400 miles per hour. It will take 60,000,000 horse-power to provide the air speed necessary to supply a 300-foot diameter wind tunnel! The fact requires analyzing however. The "landing," in other words the reduction of travel relative to earth, will probably take no more than half a minute, probably not more than a quarter of a minute. Say a minute. The horse-power involved, therefore, is 60,000,000 for one minute, and that is equivalent to a 60,000 h.p. plant working for 16 hours.

The figures are high, but the cost of flight must always be high, and there are no half-way measures. Naturally the speeds talked about—1,000 m.p.h.—are high, and there must be no thought of landing except at fixed and definite wind-tunnel-provided stations.

The future flying machine will be in the nature of a humanly guided shell—a projectile. Take the shell of present-day practice, flatten it somewhat in plan form for plane area, streamline its rear end, provide a motor and propellers, and you get the future flying machine. It becomes a projectile, launched and landed, and any intermediate landings are automatically ruled out. Such a projectile will have propellers of huge diameter, judged by present ideas (a 1,200-ton machine will have two propellers of 150 feet diameter running at 100 r.p.m.), and these projecting "sticks" alone will eliminate any possible landing gear. The high speed machine's movement of forward travel must be reduced to zero before its translation from air to earth can be contemplated. A wind tunnel, with a traveling lift to take the weight of machine when stationary, would seem essential. The expense must be high, and £100 a ton-mile may be the cost of flight in 1950. At this rate it will cost 5s. to send a one-ounce letter to Paris from London, but microphotography can reduce its cost to ½d., and the increased speed of transport will amount to an increased speed of 60 to 70 times that of the present means of travel.

A monopoly of inventiveness is not claimed and there may doubtless be other ways of landing the future high speed machines. It is conceivable for example, that it might be practicable to hang on the propellers, and so reduce forward travel to a slow vertical drop. The tail end of machine could then be received into a suitable receptacle and propellers stopped. Needless to say, there would be difficulties in this, but no insuperable objection can be seen.

Naturally, the future machine will be of different type from the present. The loading of any high speed machine must be high, and the speed variation will be very small indeed, quite possibly not exceeding 10 per cent. There will be little enough in common between the present-day and this imaginary future machine. One is a flying machine and the other is a projectile carrying its own motive power. But it is difficult to see how the present machine can greatly advance beyond its present speed except on the lines suggested. As already stated, variable surface is almost impossible; variable camber can help a little only. A much larger speed range is not likely and can never be obtained with high loading. It seems that all effort should be devoted to the problem of landing, and that forced landings between stations must be counted as to be avoided at all costs and classed as serious accidents. The problem is respectfully commended to engineers.



STRUCTURAL DETAILS OF THE FUTURE FLYING MACHINE

*From a correspondent in *Aeronautics* (London).

New Process for the Production of Aircraft Fuels*

Increasing the Yield Over Existing Practice

By Auguste Jean Paris, Jr., and W. Francklyn Paris

THE main object for which the following experiments were conducted was the development of a new method of producing high-grade aviation gasoline. Of almost equal importance was the problem of increasing the yield over existing practice, and also of reducing the cost of production.

The experimental plant was established at Charleston, W. Va., and owes its origin to the offer made to the Government during 1917 and accepted by the National Advisory Committee for Aeronautics early in 1918 for the erection of a test laboratory.

The installation consisted of a suitable building and equipment, including a six horse-power "Foos" gas engine, a 2-ton Brunswick ammonia compressor, high-pressure tanks, condensers, separators, pressure gages, etc., which, together with our services, were offered to the Government without remuneration.

PRESENT METHODS.

The universal method of producing gasoline consists of boiling crude oil in a still, similar to the boiling of water in a kettle, the vapor arising from the oil being passed thorugh a condenser, which consists of a series of pipes lying in a trough of moving water, the water playing the part of cooling the oil vapors, and thus condensing them into liquid which is removed to a cleaning outfit where it is treated with sulphuric acid to remove the unsaturated or cracked products. Sulphuric acid has a great affinity for cracked paraffins such as are produced in gasoline distillation.

The temperature at which the first drop of gasoline condenses from the distillation of crude oil differs according to the age of the oil field from which the crude oil has been obtained, and also according to the length of time it has stood uncovered since its pumping from the well. Crude oil from the Pennsylvania or West Virginia fields will start to boil a 80° F. to 100° F.; and the first drop of condensation will be found at about that temperature. This is known as the initial boiling point.

The temperature of the still is then gradually raised until it reaches the temperature at which it is desired to "cut" off the distillate. This is known as the end point or final boiling point. This latter temperature is controlled by the commercial side of the enterprise, *i. e.*, the supply and demand for gasoline. At 302° F. as a final boiling or end point the end of the real volatile products is reached; and they are about to enter the illuminating or burning oil distillates. Most of the commercial gasolines have an end point of 450° F. This is an indication of gasoline containing a large quantity of kerosene. The higher the temperature of the end point the larger quantity of unsaturated hydrocarbons will be found before cleaning.

It is the practice to clean the gasoline and remove the unsaturated hydrocarbons by a sulphuric acid treatment, removing most of the acid, neutralizing the remaining acid held in suspension by the gasoline by the use of an alkali, and washing with water. The acid absorbs the unsaturated hydrocarbons, thereby producing sulphones which in turn are washed with water.

It is our conviction that a gasoline which has not been in touch with an acid will have decided advantages over one which has. It is also our conviction that a gasoline produced without a heat treatment, such as the distillation at present universally practiced at oil refineries, would be free from cracked or unsaturated hydrocarbons, thereby eliminating the necessity for such acid treatment. A series of experiments have lately been conducted with the following results:

EXPERIMENT NO. 1.

Extraction direct from crude oil.

Raw product, West Virginia crude oil .... 42° Baumé.
Raw product, quantity used in experiment....... 44 gallons.

Gasoline produced:	Gallons.	
No. 1, 69° Baumé	5	
No. 2, 58° Baumé	10	
No. 3, 55° Baumé	5	
	— 20	
Residue, 37° Baumé	24	
	—	44 gallons.
Percent volatile products		45

No. 1 is high-grade aviation gasoline.

No. 2 is automobile gasoline.

It is our opinion that a mixture of Nos. 1 and 2 would prove to be a satisfactory aviation gasoline.

All these gasolines evaporate clean and without leaving any odor.

EXPERIMENT NO. 2.

Treatment of crude benzine or first cut from West Virginia crude oil.

Raw product, crude benzine..................... 62° Baumé.
Quantity used in experiment.................... 97 gallons.

Gasoline produced:	Gallons.	
No. 4, 65° Baumé	51	
No. 5, 59° Baumé	36	
	— 87	
No. 6, residue, 53° Baumé............	10	
	—	97 gallons.

No. 4, 65° Baumé, is aviation gasoline.

No. 5, 59° Baumé, is automobile gasoline.

TABLE I.—*Products of experiments.*

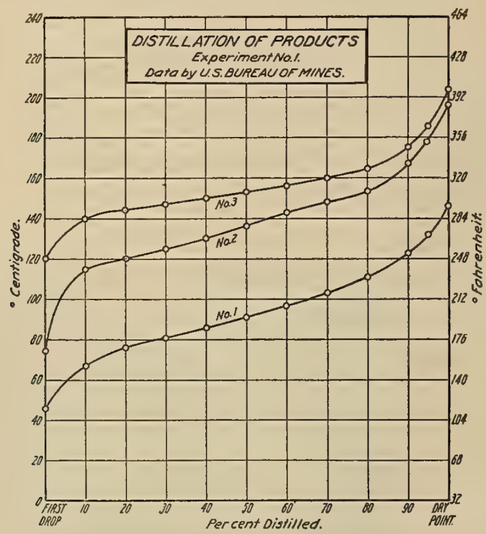
	Experiment No. 1.			Experiment No. 2.		
Product No......	1	2	3	4	5	6
Specific gravity....	0.704	0.745	0.756	0.7165	0.741	0.7645
Degrees Baumé...	68.9	57.9	55.2	65.4	58.9	53.1
Color..............	W. W.	W. W.	W. W.	W. W.	W. W.	W. W.
Odor..............	O. K.	O. K.	O. K.	O. K.	O. K.	O. K.
Unsaturated......	1.2%	1.4%	.8%	.8%	.8%	.7%
Doctor test.......	+ or −	+ or −	+ or −	+ or −	+ or −	+ or −
Acidity...........	None.	None.	None.	None.	None.	None.
Loss..............	1.5%	1.0%	1.0%	1.5%	1.0%	....

DESCRIPTION OF PROCESS USED IN EXPERIMENTS.

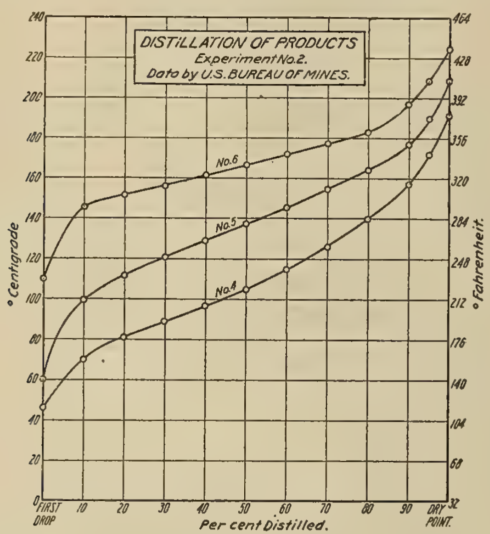
Crude oil or benzine was placed in a closed tank which was supplied with heat from a gas burner sufficient to maintain the temperature at around 200° F. Natural gas at a pressure of about 100 pounds and a temperature approximately 150° F. was allowed to bubble through the oil and thereby absorb the vapors of the lower boiling point hydrocarbons contained in the crude petroleum. This charged gas, at its then reduced pressure of about 10 pounds passed to a single cylinder refrigeration machine and was compressed to about 125 pounds per square inch. During the compression stroke a small quantity of glycerine was sprayed into the cylinder by means of the high gas pressure on the delivery side of the compressor, and mixed with the gas and hydrocarbon vapors therein. The compressed gas, with its then condensed and entrained gasoline, plus the injected glycerine, passed through a settling tank where the most of the glycerine and some of the gasoline were deposited, and then through a water-cooled condenser

*Report No. 42, National Advisory Committee for Aeronautics.

where the most of the remaining gasoline vapors were condensed. A separator was next in line and served to remove the condensed gasoline from the gas which latter was then passed through a reheater where its temperature was raised to around 200° F. by transfer of the heat of the exhaust gases from the gas engine which operated the refrigerating machine. This reheated natural gas then again passed to the tank containing the crude material and so completed the cycle.



During the experiments a small amount of the natural gas was lost by leakage or otherwise and it was necessary to admit more to the system from time to time. The glycerine which was injected into the compressor cylinder served to aid the cold water circulating through the compressor cylinder jackets to abstract the heat of compression and maintain the temperature of the compressed gas and vapors at a low point. The amount of gasoline vapor condensed from the charged gas as the result of the compression was thereby increased. The low temperature of the gas and gasoline vapors also obviated any material cracking or chemical breaking down of the



various hydrocarbons contained. It is also believed that the glycerine was to a certain extent instrumental in removing by absorption some of the impurities contained in the gasoline vapors as received in the compression cylinder.

The experiments were not carried far enough to determine the ultimate possibilities of the glycerine injection process as a means of removing water, sulphur, sulphur compounds, and other impurities from the gasoline. The apparatus used was assembled from material readily available on the market, so that the results do not represent the economic value of this distillation process.

A complete description of the several modifications of the fundamental process described in the above note is contained in patent specification No. 193624, filed September 28, 1917, and entitled "Process of cleaning and refining distillates of petroleum."

THE ABSORPTION OF MINERAL SALTS BY THE TIPS OF ROOTS.

RECENTLY we described in the SCIENTIFIC AMERICAN SUPPLEMENT the remarkable experiments made by M. Henri Coupin proving that plants absorb water by the tip of the root only, contrary to the general supposition. M. Coupin has been contniuing his experiments, of which a report has just come to hand in the Minutes of the French Academy of Sciences. His special object in these later experiments was to discover whether the root tip absorbs not only water but, as seemed highly probable, also the mineral salts dissolved therein, and to find out whether this endosmosis is sufficient to permit the nutrition of the plants. His experiments were conducted in the same manner as before, *i. e.*, the germinations were continued for several days in an atmosphere which was both aerated and humid, and the point of the root *alone* was immersed in the liquid. No matter what kind of plant was under observation this liquid consisted either of Knop's liquid (A) or of redistilled water (B). Knop's liquid is the well known and classic liquid employed in studying the mineral nutrition of plants. It contains 1 gr. of calcium nitrate, 0.25 gr. of potassium nitrate, 0.25 gr. of acid phosphate of potassium, 0.25 gr. of magnesium sulphate and traces of the phosphate of iron. It is necessary to redistil commercial distilled water, since it contains copper, which is apt to be injurious to the roots, and which is particularly likely to kill the vegetative plants. This water must be redistilled in glass. The experiments were carried on in the laboratory, whose temperature was about 20° C. in front of a window which looked towards the north and was admirably lighted. Once every twenty-four hours the germinating seeds were raised so that only the point of the root remained immersed in the water.

"The results obtained with a very large number of species being *strictly identical* three examples will suffice," says Mr. Coupin, "to prove my point. The radicles in question were placed exclusively in the humid air and not in the liquid of the culture. The three plants chosen were peas, the castor oil plant, and white lupine. Careful data were kept and a study of these shows the results to be as follows: Every plant whose root point was immersed in *Knop's liquid* exhibited a distinctly superior development to that of the corresponding plant which was immersed in the *redistilled water*. This difference is manifestly due to the fact that in the first case the nutritive salts had penetrated the root, thus enabling the plant to obtain a better growth than the one which had at its disposal only the reserve substances contained in its cotyledons or its albumen. The conclusion was inevitable, therefore, that *the point of the root is capable of absorbing mineral salts and that the latter are abundantly utilized in the growth of the plant to which they are furnished.*"

SYNTHETIC ASPHALT.

DR. ZIMMER, the director of the Johannes Jeserieh Company, Charlottenburg, has worked out a process which will enable the company in the future to manufacture solid asphalt synthetically, thus rendering it independent of raw material from abroad.

The process has already been patented in nearly every civilized country. A new factory is being erected at Velten, near Berlin, for the utilization of this discovery. The existing building difficulties make it impossible to say when a start will be made with the manufacture of synthetic asphalt.—*Chemiker-Zeitung*, May 15, 1919.

The Diesel Engine and Automobiles*

Developments Necessary to Adapt This Engine to Motor Vehicle Propulsion

By Charles Day, M. Sc.

Up to the present time, the Diesel engine has not been developed along lines suitable for automobile work, for reasons which are stated later, but it does not follow from this that such engines will be confined to their present duties, namely, that of providing motive power for power stations, factories, pumping stations, &c., and for ships.

Quite apart from the possibility of its development for automobile purposes, the Diesel engine forms a very interesting study in the application of theoretical ideas to practical engineering, and the way in which such ideas have very often to be modified to meet practical and commercial conditions. A few moments may therefore be usefully spent in very briefly outlining this point of view.

It is many years since Carnot enunciated the ideal cycle which would give an engine of the highest possible efficiency. Carnot's cycle is illustrated in the diagram, Fig. 1, which can be briefly described as follows:

From A to B the air in the cylinder is compressed isothermally, *i.e.*, without rise of temperature. From B to C (the inner end of the working stroke of the piston) the air is compressed adiabatically, *i.e.*, without transfer of heat to or from the surrounding walls. On the outward stroke of the piston, the heated air expands isothermally from C to D, and then the expansion is continued, but adiabatically, from D to A, the proportion of the various phases being such that the temperature and pressure at the end of expansion are the same as at the commencement of compression.

Accepting Carnot's as the ideal cycle, and trying to apply it in practice, difficulties are clearly apparent. From A to B the compression is to be isothermal. This condition requires that the heat equivalent of the work done in compression be completely conducted away, thus requiring that the cylinder walls be perfect conductors of heat. From B to C the condition is quite changed, as here no heat must pass away; thus it is now required that the cylinder walls be perfect non-conductors of heat. On the expansion stroke the requirements are again similarly reversed.

From this very cursory examination, it would appear that the Carnot cycle is fundamentally impossible of attainment, and so it appeared until Diesel conceived the idea of meeting Carnot's conditions in the following manner:

The cylinder walls must be as nearly as possible perfect non-conductors of heat, thus securing the adiabatic portions of the compression and expansion, while the isothermal compression would be secured by means of a suitably timed fine spray of water injected into the cylinder during the portion A to B, the isothermal expansion being obtained by spraying into the cylinder during the period C to D fuel which would be ignited and burned by the heated air, the fuel being so sprayed as to just maintain the temperature, *i.e.*, to give isothermal expansion.

This proposal attracted great interest, and seemed to open up a realization of the Carnot cycle, and of a perfect heat engine, but unfortunately the ideal has not been attained. It is, however, of interest to note the reasons.

Briefly these were that the necessary working pressures were too high, while the mean effective pressures attained were too low.

In Fig. 1 it will be noted that the net effective area is small, and is particularly so in relation to the maximum pressure. Actually the proportions are less favorable than shown in Fig. 1, as this diagram is distorted for greater clearness. Fig. 2 is more nearly representative of the actual pressures.

Perhaps the most interesting, and certainly the most valuable feature of Diesel's proposals, lies in his scheme for spraying fuel into the cylinder, the air in which had previously been sufficiently heated by compression to cause spontaneous ignition of the sprayed-in fuel, as, although other features proposed by Diesel have been abandoned, this feature remains.

The water spray during compression was soon abandoned, thus cutting out the isothermal portion of the compression. In this way the maximum pressure was much reduced owing to the fact that the temperature resulting from adiabatic compression depends upon the ratio of the initial pressure to the terminal pressure. For example, if air is so compressed from a pressure of one atmosphere to a pressure of thirty atmospheres, the resulting temperature is sufficient to ignite most oils, but if at the commencement of the adiabatic compression the air is at five atmospheres' pressure, the compression will require to be carried to thirty times five, or 150 atmospheres, to give the same temperature. From this example, the practical gain resulting from the elimination of the isothermal portion of the compression is evident.

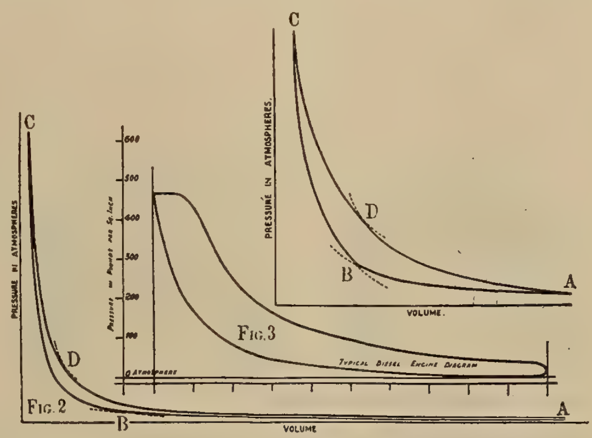


FIG. 1. CARNOT'S CYCLE. FIG. 2. ACTUAL PRESSURES. FIG. 3. NORMAL INDICATOR DIAGRAM FROM A DIESEL ENGINE

The next step was the elimination of the isothermal expansion and the spraying in of the fuel more rapidly. This increased quantity of fuel prevented the pressure from dropping so much during this stage of the expansion, and the general practice is now to introduce the fuel in sufficient quantity to maintain approximately steady pressure during the period of fuel admission. This change is illustrated in Fig. 3, which is a normal indicator diagram from a Diesel engine, and from this it will be readily seen that a very much higher mean effective pressure occurs under the new condition.

With these drastic changes rendered necessary by hard practical facts, the engine differs very materially from the original ideal, but it is of interest to note the phases of development, and it does not appear to be an unfair deduction to say that, as it stands to-day, the Diesel engine works on the nearest practical cycle to Carnot's cycle of maximum efficiency.

The feature which remains, and which is of great value, is, as has already been explained, the spontaneous combustion of sprayed-in fuel.

The Diesel engine as it stands today, differs so far from the original invention, and its development has been due to so many others than the original patentee, that the continuance of his

*From *The Practical Engineer* (London), a paper read before the Institution of Automobile Engineers.

name in association with it is, in the author's opinion, not justified, and it would therefore appear more satisfactory to adopt a technical rather than a personal title. "Spontaneous Ignition Engines" or "High Compression Engines" might meet the case, or alternatively "Spontaneous Combustion Engines." It would not be sufficiently distinctive to speak of them as "Heavy Oil Engines" or "Crude Oil Engines," as other types of engine can use such oils. Whatever title becomes generally adopted, the author is of opinion that it should indicate the fact that the special feature of the engine is the spontaneous ignition of the fuel as distinct from electrical ignition or ignition due to a hot bulb or a hot spot. The name "Diesel Engine," however, being the familiar one at present, it would seem best to retain it for the remainder of this paper.

A type of engine which during recent years has been developed to a considerable extent for small powers is called the "Semi-Diesel" engine. The name, though very widely adopted, is not, in the author's opinion, a well-chosen one, except, perhaps, from a commercial point of view. The broad distinction between semi-Diesel engines and Diesel engines is that a lower compression is adopted for the former, with the result that spontaneous ignition is not possible until the engine is warmed up—consequently, external sources of heat, such as lamps, are depended upon with a semi-Diesel engine until some portion of the combustion space has become considerably heated, after which the external heating can be discontinued.

This question has been dealt with fully in many papers, but the merits of the two systems may be summed up as follows:

Four-stroke Cycle.	*Two-stroke Cycle.*
No scavenging pump.	More uniform turning moment.
Longer time for inlet of air.	Either no inlet valves or no exhaust valves—in some engines neither.
Cooling of pistons and cylinders is easier.	With slow speed engines, weight and space occupied rather less.
Higher mean pressures are attained.	
Lower fuel consumption.	

Turning now to the consideration of the application of the Diesel engine to automobile work, the method of introducing the fuel into the cylinder and the conditions of combustion are at present the limiting factors.

In regard to the spraying of the fuel into the cylinder, it will be readily appreciated that time is a factor in forcing oil through a pulverizer, also that as the viscosity of the oil increases, the time required to force the oil through will increase, unless the pressure behind the oil is increased, or the design of the pulverizer modified. With free flowing petroleum residue oil, and with an air pressure of about 1000 lb. per square inch, the author is of opinion that pulverisers of prevailing designs can, with suitable oils, be arranged to deal with speeds up to about 500 or even 600 revolutions per minute. At 600 revoutions per minute the time during which the oil has to be sprayed into the cylinder is approximately 1/200 of a second. For higher speeds pulveriser modifications will need to be developed.

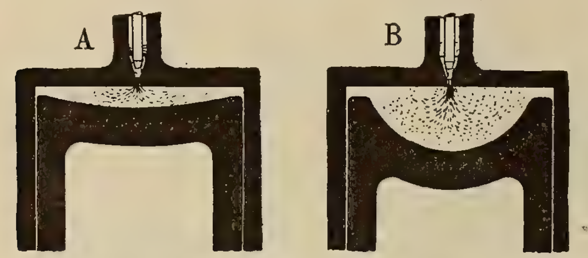


FIG. 4. BEST COMBUSTION SPACE FOR A SHORT STROKE ENGINE

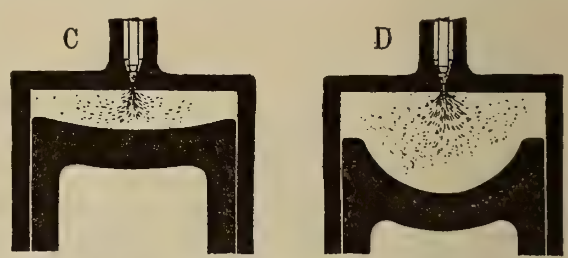


FIG. 5. COMBUSTION SPACE AT LATEST POINT OF FUEL ADMISSION

The system of introducing the fuel in Diesel engines carries with it the following advantages:

(*a*) Pre-ignition cannot occur, as air only is present in the cylinder during compression.

(*b*) No sparking plugs or heated bulbs are used.

(*c*) No carburetors or vaporizers are required, the fuel being sprayed direct into the cylinders.

(*d*) The engines are ready to start at any moment, no previous heating up being required.

Most makers of this class of engine have adopted and still prefer the four-stroke cycle already described, but a great deal of work has been done on the two-stroke cycle, and many quite successful engines have been made on this latter cycle. The fact that in Diesel engines air alone is taken into the cylinder, and not air mixed with gas or with oil spray or vapor, makes this engine particularly suitable for working on the two-stroke cycle. In those engines where the fuel is taken into the cylinder along with the air, there is great risk with the two-stroke cycle of some of this fuel being carried away with the outgoing exhaust which is displaced by the incoming gases. Obviously, this loss of fuel is eliminated if air alone is taken into the cylinder.

Another feature to be kept in mind is that the very short period of the stroke during which the air is taken into the cylinder renders the two-stroke cycle less suitable for high speeds of revolutions than the four-stroke, but, on the other hand, this disadvantage is at a minimum with engines which run at the slow speeds of revolution generally desired for cargo ships. Consequently the two-stroke cycle engine has been developed more for marine propulsion than for purposes where higher speeds are advantageous.

The character of the fuel oil is a factor in the permissible engine speed, both from the point of view of pulverisation and of combustion. Viscous oils are more difficult to pulverize than thin and free flowing oils, and cannot be put through a pulverizer so quickly.

Again, the combustion of heavy and tarry oils is not so rapid as that of refined oils, such as paraffin or petrol, and if the engine speed is so high as not to allow sufficient time for the combustion of the fuel, difficulties will arise from sticky valves, smoky exhaust or dirty cylinders. For rapid combustion a very finely divided spray is of importance, as obviously large drops of oil take a longer time to burn than very small ones.

From this it would seem that high speed engines may need refined oil, in which case one of the great advantages of the Diesel engine will disappear.

The fuel sprayed into the cylinder during a very short period of the stroke, commencing with the piston at approximately the top of the stroke. With a short stroke engine the combustion space into which the oil has to be sprayed is very shallow, as owing to the high compression necessary the clearance volume must be low, say, about 7 per cent. of the total cylinder volume. Remembering the small clearance space, the difficulty of spraying the oil so as to distribute it throughout the air is obvious. Failure thoroughly to mix the oil spray

and air will lessen the possible power of the engine by reducing the quantity of oil which can be burnt.

Improvement in distribution is obtained by dishing the piston top. Fig 4, A, shows diagrammatically the best obtainable combustion space for a short stroke engine, assuming reasonable clearance between the outer edge of the piston top and the cylinder head, while B shows the possible shape of combustion space if the stroke of the piston is doubled.

The combustion space at the latest point of fuel admission is shown in Fig. 5 by C and D respectively. A glance at these diagrams shows how much easier the spraying problem becomes in the long stroke engine than it is in the short stroke engine, especially when it is remembered that it is desirable to avoid spraying or splashing the fuel oil upon the water-cooled cylinder head or on the piston.

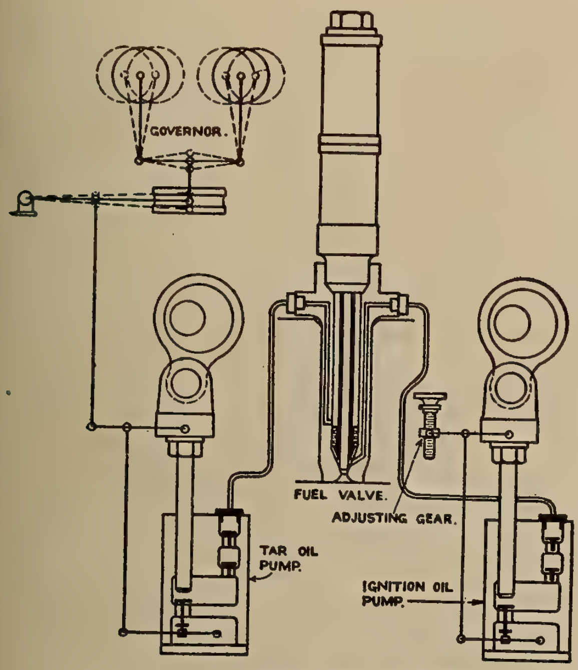


FIG. 6. PILOT IGNITION SYSTEM

In connection with gasoline engines much attention has been given to the production of a turbulent condition of the gases at the time of ignition, but in the author's view such a condition at the commencement of spraying is not so important in a Diesel engine; but, on the other hand, a considerable amount of turbulence should result from the spraying in of the oil so as to ensure the utmost possible mixing of the oil and the air.

Another factor which must be kept in mind for automobile work is range of speed. In the Diesel engine ignition depends upon the temperature of the air at the end of compression, but if the speed of the engine is reduced very much it may happen that the cooling effect on the slowly compressed air is enough to prevent the compression from raising the air temperature sufficiently for ignition. There is thus a limiting factor to the slowness of speed, and the range of speed permissible with the Diesel engine is not so great as with gasoline engines, in which the ignition is obtained by means of a spark.

Before Diesel engines are likely to be applied extensively to automobile work, development along the lines indicated will be necessary, so that higher speeds of rotation can be adopted and reduction of space and weight thus secured.

The difficulties to be overcome before the Diesel engine is suitable for automobile work have been stated, but it is important to make clear that the expression "automobile work" is not intended by the author to cover locomotives, for the Diesel engine as at present developed is applicable to locomotive work, and should find an important fields there, owing to the great economy of working. For outlying districts and for long journeys through sparsely populated areas and countries, locomotives operated by Diesel engines should prove very advantageous, as for such districts electrical operation from fixed power stations is unsuitable.

Compared with the steam locomotive of existing types, the internal combustion locomotive would be cheaper in fuel, and would, if operating electrically, give much higher torque both when starting and when climbing stiff gradients, and it would also use a much smaller quantity of water. Reliability in service and a reasonable cost of upkeep will come with experience. The elimination of stand-by losses and immediate readiness for use are factors of importance in this service.

Fuel Oils.—A very wide range of fuel oils can be used in Diesel engines, as, for instance, petroleum residues, tar oils, some crude tars, shale oils, kerosene, naptha, alcohol or gasoline. Gasoline is only mentioned to illustrate the wide range of fuels permissible, and not as a desirable fuel, for obviously the much cheaper oils would be selected. As already explained, the working of the engine depends upon the spontaneous ignition of the oil when sprayed into the hot air in the combustion space—hence the temperature at which the spontaneous ignition of different oils occurs is a matter of importance. Information on this point being meagre and scattered, Messrs. Mirrlees, Bickerton and Day, Limited, a few years ago carried through in their laboratory a series of investigations on this subject, and from them obtained a lot of useful data, of which the following is an abstract.

Spontaneous Ignition Temperature of Different Oils.

	Spontaneous ignition temperature in oxygen. Degrees C.
Gasoline, No. 1	272
Gasoline, No. 2	270
Kerosene	252
Gas oil	254
Petroleum fuel oil	260
Shale oil (Broxburn)	253
Tar oil	470
Coke oven tar	494
Water gas tar	464
Blast-furnace tar	498
Whale oil	273
Naphthalene	402
Alcohol	395

From these figures it will be noted that the tars and tar oils have much higher spontaneous ignition temperatures than petroleum oils. This means that a degree of compression which will raise the compressed air to a sufficient temperature to ignite petroleum may be insufficient for tar oils—hence engines working on tar oils should have either higher compressions or some other means of raising the temperature of the air. The most widely adopted method is that known as the Pilot ignition system, which is illustrated diagramatically in Fig. 6, a small quantity of petroleum oil is injected into the cylinder in advance of the tar oil, and by its combustion raises the temperature sufficiently to ensure the ignition of the tar oil which follows it. The tar oil is delivered to the fuel valve by the main fuel pump, and enters the space round the fuel valve spindle at a point just above the pulverizer, in the usual manner. A separate pump supplies the ignition oil, and delivers it through another passage in the fuel valve casing to a point just above the inlet to the cylinder. When the fuel valve opens, the ignition oil, being below the tar oil, will enter the cylinder first, and immediately be burned. The combustion of this small charge of ignition oil will, as already stated, raise the temperature in the cylinder to such a degree as to ensure ignition of the tar oil which forms the remainder of the fuel charge.

The use of Diesel engines in power plants ashore, for marine propulsion and for auxiliary power on board ship, has been so fully dealt with in numerous papers that the author does not

propose to deal with these aspects at length; but the Diesel engine is specially applicable in the following circumstances:—

(1) Where power is required at very short notice.

(2) Where the space for power plant is very limited.

(3) Where the load is of short duration, as, for instance, in many electric light stations, as stand-by losses are eliminated.

(4) Where labor is difficult to obtain.

(5) Where the stoppage of a public supply, owing to a strike, would cause great loss or suffering.

(6) Where smoke and pollution of atmosphere must be minimised, and pollution of streams avoided, where chimneys would be unsightly, or where coal dust or ashes are objectionable.

In addition, there are many districts and countries where the relative prices of oil and coal are such as to render the Diesel engine advantageous for almost every purpose.

Even in situations favorable to steam or to gas engines, many occasions will arise in which an engine of the type under consideration can with advantage be installed—for instance, as a spare which can be immediately started up in case of trouble with a boiler or with gas plant.

Some collieries are even now considering the installation of Diesel engines arranged so that pumping operations can be maintained during strikes. The small amount of attention necessary is an important feature of this scheme.

Diesel engines have been successfully used for almost every industrial purpose for which power is required, and their adoption is steadily increasing.

The Impact Testing of Metals*

Types of Machines Designed for Conducting the Tests

By F. C. Thompson, D.Met., B.Sc.

THE introduction of rapidly moving and severely stressed parts in engineering design, especially, perhaps, in motor-car and aeroplane construction, led to a search on the part of engineers for a test in which rapidly applied stresses were involved which should supplement the ordinary tensile test where the rate of loading is relatively slow. The work of Eaton Hodgkinson (1847) and Wöhler (1859) paved the way for the so-called "fatigue" tests in which fracture of the sample is brought about by the rapid repetition of stresses often considerably below the elastic limit as determined in static tension. Many types of such test, which for some time enjoyed considerable popularity, have been devised, but in recent years, and especially during the war, in connection with the inspection of material for air-craft construction, the fashion has changed. The "impact" test, in which fracture of the test-piece is effected by a single sudden blow, has replaced the fatigue test, in some forms of which millions of repetitions of comparatively small stresses were required.

The literature of the subject is now somewhat voluminous, and an interesting bibliography is to be found in a paper by Dr. W. H. Hatfield[1].

The earlier work on impact testing revealed most exasperating discrepancies in the resistance of presumably the same material to sudden and severe stresses. For several years a controversy was carried on between those who claimed that a form of test which yielded such discordant results on samples which, so far as the usual methods of testing were concerned, were identical, was not worthy of credence, and those who saw in it a method so sensitive that variations shown by no other process were revealed. The latter view has been shown beyond doubt to be correct. Especially as a result of the work of Charpy and Cornu-Thenard[2] it has been demonstrated that, given really uniform material, results agreeing within 1 or 2 per cent, can be obtained. It is, therefore, to variations in the steel under test that the apparent discrepancies observed are to be ascribed, this form of test now standing out as probably the most sensitive of all those used in the testing of materials of construction. The impact test has thus at last come into its own, and both as a method of research in determining the best treatment for any given steel, and as a method of routine inspection, has been widely adopted.

It has long been known that the special sensitiveness of this test was not displayed where plain bars of metal were employed; from some form of notched test-piece only was the full information obtainable to be procured. Many varieties of notch have been suggested and used, but the fairly general consensus of opinion is now that a fairly sharp notch is best. When comparing the V notch with the "Copenhagen" type, in which a straight cut ends in a cylindrical hole of relatively large diameter—2 mm.—the superior sensitiveness of the former in picking out brittle material is clearly shown. Since this constitutes the whole *raison d'être* of the test, the marked preference for the sharp notch is obviously justified. Although the radius at the base of the V should be as constant as possible (0.25 mm.), slight variations in this do not make sufficient difference to invalidate the test. The Mesnager notch, much used in France is 2 mm. deep, ending in a semicircular groove of 1 mm. radius. The work of Philpot[3] has shown that results of the same order as those obtained from impact tests are given by slow bending tests on similarly notched bars, and it would, therefore, appear that it is to the noched test-piece rather than the suddenness of the blow that the remarkable results are to be referred. Since, however, the notched bar test is more rapidly carried out in its impact form, this is the one which finds the chief application. To the subject of the notch repeated reference will be made below.

Concerning the types of machine designed for conducting impact tests, two distinct forms are in use, in which fracture is brought about by single and repeated blows respectively. The latter form of the test, of which the apparatus due to Dr. Stanton is the only one which need be referred to, occupies a position midway between the "fatigue" tests and the impact test proper. The test-piece, ½ inch in diameter and 6½ inches long, is placed on supports 4½ inches apart. A groove, which in the form supplied by the Cambridge Scientific Instrument Co. is 0.05 inch deep and 0.05 inch wide, is made round the centre of the bar, the corners of the notch being practically square. This bar receives blows from a hammer weighing 4.7 lb., the height of fall of which can be varied. The test-piece is rotated through 180° after each blow, about 100 of which are given per minute. The number of blows endured before fracture occurs at the groove is recorded. In the paper by Hatfield to which reference has already been made, results are given which reveal a very close connection between the resistance of steels to the Stanton test and their true elastic limits. Something much more than this is required if the impact test is to justify its existence, with the result that this modification of the test finds but limited application, the

*From *Science Progress*.

[1]*Pros. Inst. Mech. Eng.*, 1919, p. 347.

[2]*Journ. Iron and Steel Inst.*, 1917, ii, p. 61.

[3]*Trans. Inst. Ant. Eng.*, April 1918.

single-blow variety being far more commonly employed. The results obtained from these two types of impact tests are often widely discordant, materials which, according to one test, show marked resistance to impact making a poor show when tested by the other.[4]

In all the machines in common use for conducting impact tests a band test is employed. Other types have been suggested, but have found little or no support. Stanton and Bairstow[5] have described and figured an apparatus designed for carrying out impact tensile tests. Four forms of impact bend test are in fairly common use. The two best known of these, the Izod and Charpy types, both employ a falling pendulum to strike the blow. The Frémont machine has a vertically-falling weight, while in the Guillery apparatus a rapidly revolving fly-wheel is used to impact the blow. The essentials of each form are as follows:

In the Izod test the piece, 10 mm. square with a V notch 2 mm. deep at an angle of 45°, is clamped vertically with the height, and at the lowest point of its swing a knife edge which it carries strikes and breaks the test-piece. The residual notch on a level with the face of the die and facing the pendulum. This is released by a spring attachment from a given energy is measured by a pointer which is moved over a graduated scale as the pendulum rises. The height of fall of the centre of mass of the pendulum is 2.5 feet, the striking velocity 13.6 foot-seconds.

The Charpy test differs from the foregoing chiefly in that the test-piece is loosely supported at both ends, the distance between the supports being 40 mm., and that the notch is placed on the opposite side of the test-piece to that on which the blow is received. Although, of course, a notch identical with that used in the Izod test can be and often is used, the specified form consists of a cut 5 mm. deep, terminating in a cylindrical hole 1 1-3 mm. in diameter. The knife edge which comes in contact with the test-piece is here placed vertically in the pendulum; in the Izod machine it is horizontal. In the machine of the usual size the weight of the tup is 22.5 kilograms, the striking energy being 30 kilogram-metres.

In the Frémont test the blow is received from a tup which has fallen vertically through a height of several metres, the striking velocity being higher than in either the Izod or Charpy forms. The test-piece, 8 mm. by 10 mm., rests horizontally on supports 21 mm. apart, with a square notch 1 mm. deep and 1 mm. wide on the longer lower side.

The standardization of the impact test is, as a result of the work of Charpy and Cornu-Thenard, now fairly complete. Despite the differences in the types of apparatus described, the results obtained from similar samples with the same form of notch on all of the machines are practically the same. Not only is the type of machine without influence, but so also is the energy of the blow, provided that this is ample to produce fracture. The work done in breaking the test-piece is, therefore, a definite characteristic of the material.

The results of the test are commonly expressed in terms of the difference in energy of the tup before and after fracturing the test-piece. As Mr. H. Brearley has pointed out, the work done upon the material is expended in the first place in starting the crack at the root of the notch, secondly in extending the crack across the bar, and thirdly in deforming the material in the neighborhood of the crack. In view of this complexity, it is not surprising that no satisfactory general connection has so far been discovered between the dimensions of the bar and the work done in fracturing it in impact. All that it is at present possible to do is to record the work expended in breaking a clearly specified but quite arbitrary type of test-piece.

The unfortunately fairly common practice of expressing these results in such terms as kilogram-metres per square centimetre is most unsatisfactory. The energy used up in breaking, say an Izod test-piece 0.8 sq. cm. in cross-section at the notch, when multiplied by 1.25, does not give the energy required to fracture a test-piece whose dimensions are 1 cm. $\times$ 1 cm. at the base of the V. It has been suggested by Mimey[6] that if T_1 and T_2 are the energies absorbed in fracturing two geometrically similar bars of the same material, then $\frac{T_1}{T_2}$ will be proportional to the cube of the homologous dimension, provided that

$$\frac{M_1}{M_2} = \frac{\sqrt{H_1}}{\sqrt{H_2}} = \frac{D_1}{D_2} = \frac{\sqrt[3]{T_1}}{\sqrt[3]{T_2}}$$

where M_1 and M_2 are the masses of the weights, H_1 and H_2 the distance fallen, and D_1 and D_2 the distance apart of the supports for the test-piece. The result is not, however, in agreement with experiments, except where deformation does not proceed as far as the fracture and in the case of untouched bars. For purposes of reducing the results obtained in ordinary impact tests on notched bars, it is useless. In the case of a bar of side χ and notched with a standard groove, the total work done in producing fracture would require a formula of three terms of the form $\alpha\chi + \beta\chi^2 + \gamma\chi^3$. The first term corresponds to the energy expended in starting the crack along the line of the notch, the second to that done in carrying it across the section of the test-piece, and the third to that used up in deforming adjacent material. Since it is often comparatively easy to continue the crack when once it is formed, the importance of the first time—neglected by Charpy and Cornu-Thenard—is evident. The relative part which each of these factors plays will vary considerably in different materials. In, for instance, a hardened steel the resistance to deformation is very great. A crack, therefore, once started extends with ease and without appreciably deforming the surrounding material. A low impact value will thus be recorded. In the case, however, of a metal or alloy with a fairly low yield-point, it may not be possible either to start or to propagate the crack without considerable distortion of the surrounding material. In this distortion considerable energy is used up, with the result that a high impact figure will be given. It is not, therefore, possible to draw any hard-and-fast and say that above such and such a value a material is tough, and below that value brittle. For a steel with a maximum stress of 100 tons per square inch, an impact value of 30 foot-pounds would be extraordinarily good; if the same figure were associated with a tenacity of 60 tons per square inch it would be moderate, while for a 20 or 30 ton steel it would be distinctly poor.

In a crystalline aggregate, as all metallic test-pieces are, both the crystalline portion and the intercrystalline surfaces make their influence felt. As pointed out by Mr. H. Brearley, brittle materials, which, like hardened steel, yield low impact figures, break between the adjacent crystals, which are hardly affected at all. The fractured surface of a brittle test-piece is strikingly crystalline. In the case, however, of a tough sample in which the intercrystalline strength exceeds that of the crystalline portion the reverse of the foregoing conditions obtains. The crack must pass through the crystals themselves; in so doing considerable work is done on the surrounding parts, and a fibrous or silky fracture is shown. The transition of a hardened steel from the brittle to the tough condition on tempering is in part at least due to the softening of the crystalline material, rather than to increased strength of the intercrystalline areas; and in determining at what temperature any given steel should be tempered to yield the toughest product, the impact test gives the highest results when tempering is carried out 50—100° C. below the carbon change-point. To the impact test, therefore, a hard material composed of large crystals is

[4] A considerable amount of information concerning the relationship of the Stanton to other tests will be found in the *Journ. Iron and Steel Inst., Carnegie*, vol. vi, p. 94.

[5] (*Proc. Inst. Mech. Eng.*, 1908, p. 889)

[6] (*Revue d'Artillerie*, July 1911)

typically brittle, a more finely crystalline and softer one tough.

In the case of a forged material, such as steel, the resistance to impast is closely bound up with the direction in which the test-piece itself is cut. A sample cut longitudinally will yield far better results than one cut transversely to the direction of forging. The following results[7] will illustrate this influence:

Angle of Notch with Direction of Rolling.	Work absorbed on Rupture (Kilogram-metres).
0°	1.3
20°	1.5
45°	3.4
90°	13.5

The explanation of these differences lies in the alinement of brittle impurities in the steel as a result of the rolling. Sulphur and phosphorus, present as manganese sulphide and as a solid solution of iron phosphide respectively, are present in long-drawn-out threads elongated in the direction of the forging.

The presence of slag in the steel, which will also be drawn out in the direction of the rolling, deleterious as it is from nearly every point of view, may yet exert a considerable influence in raising the resistance of the material to the impact test, provided that the test-piece be cut in a longitudinal direction. As the crack formed reaches a slag inclusion, which is perpendicular to the direction in which it is growing, a tendency exists for a change of direction, the crack traveling along the line of the slag. Oriented in this way, slag fibres give an increased resistance to impact. If, however, as in a transverse test-piece, the slag lies parallel to the crack, it merely greatly facilitates its passage through the material, very low impact values being obtained. This point is very clearly dealt with by Mr. H. Brearley.[8]

The greatest triumph of the impact test has been the revelation of a new and quite unexpected type of brittleness to which certain alloy steels, especially those containing nickel and chromium were liable. Tempered at temperatures around 600—650° C., and slowly cooled, the resistance of the steel to impact may be almost non-existent, while when rapidly cooled from the tempering temperature, the resistance is excellent. This phenomenon, usually known as "temper-brittleness," is frequently not revealed at all by the tensile test, as the following figures, due to Mr. Brearley (*loc. cit.*), clearly show:

		A	B
Yield-point	*tons per sq. in.*	45.0	45.6
Maximum stress	*Per sq. in.*	53.7	52.4
Elongation	*per cent.*	21.0	21.0
Reduction of area	*per cent.*	55.8	59.3
Impact value	*ft.-lbs.*	2.5	76.5

The two sets of tests were carried out on the same material similarly treated, except that sample A was slowly cooled in the furnace after tempering, B being quenched in water. Although the tensile test is to all intents and purposes unaffected, the resistance to impact of A is only 3 per cent. of that of B. Steels of certain compositions show the brittleness fully; the rate of cooling from the tempering temperature is the essential point; a steel which has become tough or brittle may by appropriate re-treatment be rendered the reverse; no structural change has so far been observed between the brittle and tough states and finally certain casts of steel can never be rendered tough or others brittle. No explanation fully covering the facts has yet been given.

[7](*Journ. Iron and Steel Inst.*, 1918, ii, p. 24.)

[8]The notch being perpendicular to the test-piece, this sample is cut transversely to the direction of rolling.

Depth Bombs as Guides for Navigation in Fogs*

Destructive Range of Underwater Explosives

By Prof. J. C. McLennan, O.B.E., F.R.S., Scientific Adviser to the British Admiralty

IN the early days of the anti-submarine campaign, a method of destroying submarines whose approximate location was known, was by the employment of depth charges. To use this means it was necessary first of all to know the neighborhood in which it was necessary first of all to know the neighborhood in which the submarine was located, and then the chasing ship would rush to the spot and drop or throw to some distance charges of explosive which detonated when they reached a definite distance below the surface of the water. The necessity of knowing the destructive zone of any given type of depth charge soon became evident, *i. e.*, to determine the radius from the exploding charge, within which a submarine would be successfully destroyed. The same information was important in the laying out and use of minefields. Investigations were undertaken to determine what pressures were generated by charges of different sizes and types at various distances from the place of detonation. The nature of the pressure wave was particularly important, for upon it depends the "killing power" of the charge. The laws which govern the alteration in form and power of waves generated by these explosions had to be determined in order to employ depth charges and mines in the most effectual and economical manner. The accurate determination of the velocity of propagation of the explosive waves generated was also of importance in distributing the charges, for if waves from two different sources arrive at the object in different phases, the effective crushing power may be considerably altered. When we know what the effects of different charges at various distances is—what type of pressure wave, whether a sudden intense blow lasting a few ten-thousandths of a second, or a series of less intense shocks, has the greater effect in destroying the submarine when under water, then we shall know how best to lay out our minefields, and what size and type of charges are the best and most economical to utilize under the various situations which may arise.

A most elaborate investigation of the characteristics of explosion pressure waves has been carried out for the Admiralty by Mr. H. W. Hilliar. By this method the pressure is allowed to act on one end of a steel piston, and measurements are made of the velocity of the piston as it passes a series of points at known distance from its starting point. From these measurements it is only a mathematical operation to extract the acceleration of the piston at different times from the moment when it began to move; in other words, the time history of the pressure acting on the piston. It is not actually feasible to measure the velocity of a single piston at different stages of its travel, but you get the same information if you let the pressure act on a series of pistons and measure their velocity after they have travelled different distances. The velocity is found from the extent of crushing of a copper plug which the piston strikes when it comes to the end of its travel.

As an illustration of results obtained by the method it may be stated that with the measuring gages at a distance of 50 feet from a 300-pound detonating charge of amatol placed

*Abstract from a paper read at the Victory Meeting of the North-East Coast Institution of Engineers and Shipbuilders in Newcastle-on-Tyne.

about 50 feet below the surface, the corresponding time-pressure curve showed that the maximum pressure, 0.80 ton per square inch, was reached almost instantaneously; that the pressure fell to ¼ of its maximum value in 1/1,000 of a second, and practically faded away after 5/1,000 of a second. In the course of the investigation it was shown that the pressure waves are reflected from the water surface as waves of tension. The effect at any given point in the neighborhood of the explosion is, therefore, due to the superposition of a direct pressure wave from the charge and a reflected tension wave from the surface; both travel with the velocity of sound 4,900 feet per second) and the tension wave follows the pressure wave after an interval determined simply by the difference in the length of the direct and reflected paths from the charge to the point in question.

It has been found that the pressure from a large charge is more intensive and more sustained than that from a small one, the two being connected by the following rule. If one charge has twice the linear dimensions of another (8 times the weight) the maximum pressure at a given distance from the larger charge will be the same as at half the distance from the small charge and will be twice as sustained, *i. e.*, will take twice as long in falling to any given fraction of the maximum.

When explosions of gunpowder, for example, were investigated, it was found that the pressure rose much more gradually than when charges of amatol or T.N.T. were used. With this explosion very low maximum pressures were obtained and the corresponding pressure waves were considerably prolonged.

Another method of investigating such pressures, which was suggested by Sir J. J. Thomson and applied by Mr. D. A. Keys, consists in the employment of the phenomenon long known to scientists, namely, that certain crystals become charged with electricity when subject to pressure. The amount of the charge produced is proportional to the pressure applied to the crystals, so by having a suitable arrangement for measuring this charge and its variation with time, a complete record of the variation of pressure with time is obtained by placing the crystal detector at any given distance from the exploding charge. Since the duration of the wave in passing over the crystal or engulfing a submarine is only a few thousands of a second and the pressure generated may be of the order of half a ton or more per square inch, one can readily imagine the difficult nature of the problem in hand. But by making use of the inertia of a beam of cathode ray particles and employing the fact that they carry negative charges and are deflected by electrostatic and magnetic fields, it has been possible to obtain records of the variation of such pressures with the time. The electrons affect a photographic plate, *i. e.*, they leave an impression on the plate where they strike it. This additional fact has made it possible to determine the charge in pressure of the wave from the instant the charge is fired and at as small intervals as we please afterwards. Changes which take place in 1/100,000 of a second have been recorded by this means! Already the method has revealed a number of facts about the nature of the pressure wave produced by exploding charges and the importance of such results in the laying out of minefields and the employment of depth charges can hardly be over-estimated.

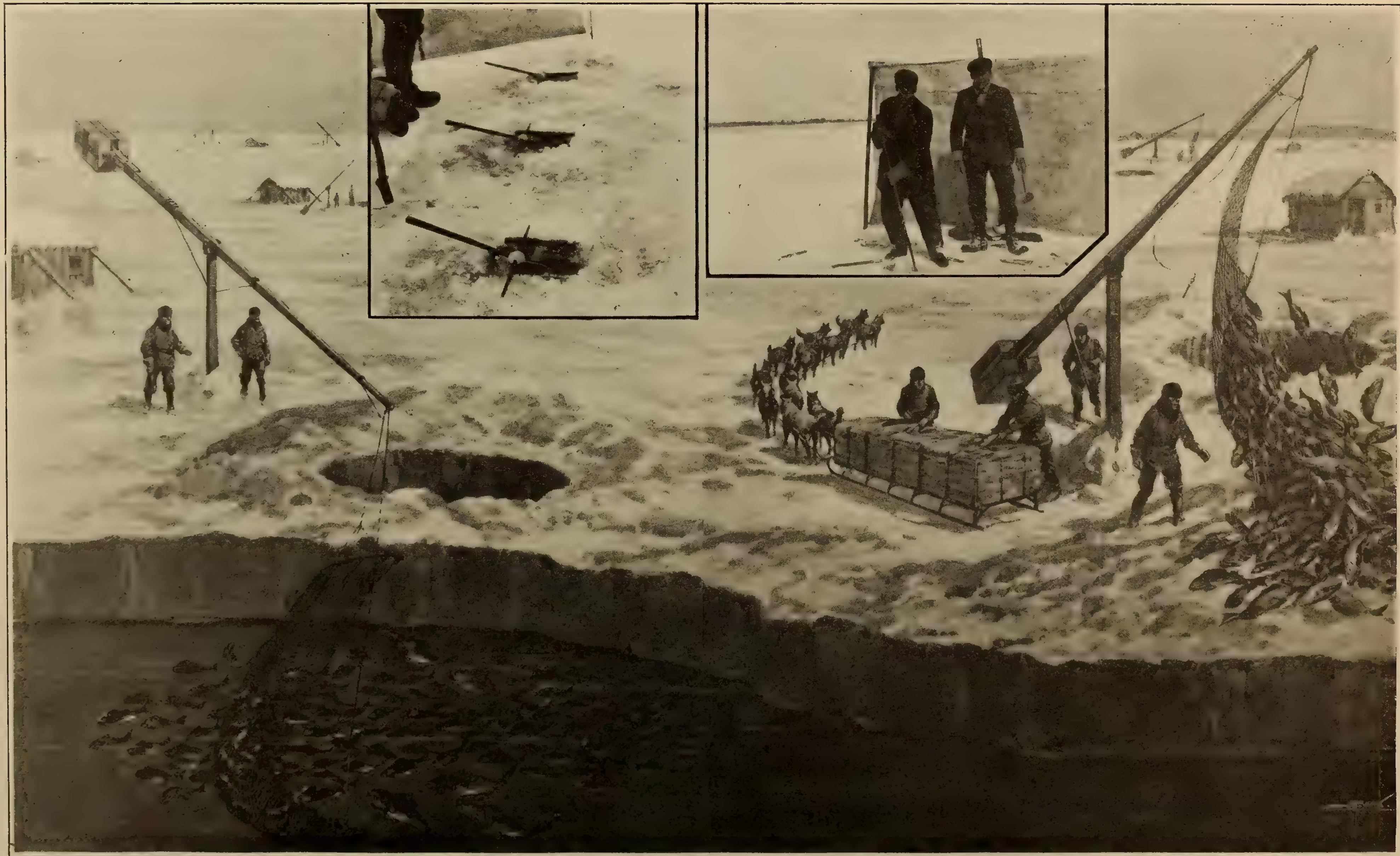
In the course of our investigations of the characteristics of pressure waves generated by the explosion of charges in the sea, it was found that when a hydrophone was used to pick up the waves a good record could be obtained by the explosion of a number 9 detonator at least two miles away. The explosion due to charges of 2 lbs. of T.N.T. have been recorded at 14 miles, and might have been recorded at far greater distances judging from the strength of the signals received. The explosions of 300-pound depth charges have been recorded up to 200 miles, and it is probable that with charges of moderate amount explosions occurring as far away as 500 miles can be readily recorded. Based on these results a system of sound ranging under water was developed. Four hydrophones were laid out 5 miles apart along a base line in deep water a mile or two from the shore and in addition two pilot hydrophones were placed along a line at right angles to the base line, the one 5 miles out and the other at twice that distance. Cables were laid from the hydrophones to a recording instrument situated in a shore station. Four of these stations were installed at different places along the east coast of the British Isles, and other stations are now in progress of installation. With such sound ranging systems the shock of distant explosions occurring under water affect the various hydrophones in turn and as time intervals can be read to 2 or 3 thousandths of a second with the apparatus now in use, it is possible to measure with accuracy the time intervals between the times of arrival of a sound wave at the different hydrophones. With the measurements of these time intervals it is a simple matter to deduce the position of the point at which the explosion setting up the wave is located. Up to 50 miles the location of an explosion under water can be determined to within a few hundred yards by a single station, but for accuracy the coöperation of two stations would be necessary to locate explosions at greater distances. Within operable ranges a ship can be given its position by sound ranging more accurately than by directional wireless or by any other known method. Explosions of mines or torpedoes at any point in the North Sea can easily be located by stations situated in Great Britain. In the war, during the bombardment of the Belgian coast it was a common thing for a monitor to proceed in a fog to a position some miles from the coast and by dropping depth charges have its position accurately determined from stations on the coast of England. So accurately was this done that it was found when the monitor's guns were trained in selected directions objectives several miles inland could be hit with regularity and with a minimum expenditure of ammunition.

SHALE AS FUEL IN ESTHONIA

The following appeared in the *Esthonian Review*, a weekly published by the Foreign Office of the provisional Esthonian Government, in its issue of October 15, 1919:

We are employing shale in Esthonia now for all manner of purposes; for instance, the Reval gas factory is using it exclusively for producing gas. It cannot yet be burnt as fuel in the fire boxes, at any rate, not as they are constructed at present, because of the large quantity of ash, and the factory, therefore, is using wood as fuel. The quantity of gas obtainable from the shale is greater than from coal. The Reval factory has obtained up to the present 120,000 poods (4,333,500 pounds) of shale. The Port-Kunda cement factory has recently purchased 60,000 poods (2,166,750 pounds) from the Ministry of Trade and Commerce and has a similar amount ordered. It is intended to employ shale mixed with 50 per cent of coal dust in the manufacture of cement.

Experiments in firing locomotives with shale have given very satisfactory results, and the railway factory in Reval is now reconstructing the fire box on one of the engines with the intention of employing shale as fuel. During a recent excursion to the island of Naissaar (Nargo), undertaken by a special commission in order to acquaint themselves with the local conditions, shale was employed exclusively as fuel in place of coal. The experiment turned out quite satisfactorily, a head of steam being obtained equal to that when coal is employed. The difference in cost is remarkable, the price of coal at present being no less than 30 marks a pood and that of shale only 3 marks, so that even if the consumption be more than double, a great saving would be effected. The engineers are of the opinion that when the fire boxes are made suitable for the employment of shale, it will be much cheaper to use this fuel than coal.—*Diplomatic Commissioner Thornwell Haynes*, Helsingfors, Finland, Oct. 18, 1919.



FISHING THROUGH THE ICE IN THE GREAT LAKES WITH AUTOMATIC BRAILING-NETS

Holes 10 to 12 feet in diameter are cut in the ice and huge automatic dip nets are set. When a sufficiently large catch has entered the net a trigger-pin is jerked loose, a counter weight raises the net and swings it clear of the hole and the net is opened, spilling the fish upon the ice. Fishing with lines is shown in the inserts; at the right hacking a hole in the ice; at the left, indicators which fly up when a fish bites.

Fishing Through the Ice in the Great Lakes*

Automatically Operated Dip Nets

By Winston Fleming

THE Great Lakes of Canada yield millions of pounds of winter-caught or frozen fish every year, a lare part of which is shipped to the United States. The lakes of northern Minnesota and Wisconsin also supply hundreds of thousands of pounds of this food. The total yearly production of this food now approximates 125,000,000 pounds.

Frozen fish in large quantities are shipped to the big cities of the United States every month during the cold weather, where they are sold at less than one-third the price of fresh fish, and still bring a good profit.

The fishing is done through the ice, sometimes miles from the shore, the fishermen living for months at a time in the tents or houses that they have built on their fishing "grounds."

Large holes, perhaps ten or twelve feet across, are cut in the ice and huge dipnets set—nets that will bring out hauls of hundreds of fish at a time. Because of the intense cold the man in charge of the holes must keep going from one to another to prevent the ice from closing his "shaft." At certain intervals a "brailer" makes the rounds and with the net man's assistance pulls up the net and empties the fish on the fresh, crisp snow that is spread on the ice to receive the catch. This snow is necessary to prevent the fish from freezing solid to the ice.

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A LONE FISHERMAN MAKING A CATCH WITH A HOOK AND LINE THROUGH THE ICE

The fish are stacked in great piles, with a blanket of snow between each layer of fish. When the fish are solidly frozen they are loaded in horse or dog sleds and hauled to the nearest shipping point. In the case of the lakes of the Far North this means a haul of several thousand miles—usually by dog team. It is estimated that the fish can be stacked, ready for hauling, in the Great Slave and Bear Lakes at about a half-cent a pound and can be delivered at Edmonton or Calgary at about three and one-half cents a pound—or can be carried on to the States for approximately two cents a pound more. Some idea of the size of this industry is indicated by the fact that in a single day 116 cars of frozen fish went over the main line of the Canadian Pacific Railroad from Edmonton to the States.

The largest fishing operators, however, do not now depend upon hand labor, but have automatic brailing nets instead. These nets automatically swing themselves out of their shafts and empty their catches into the loose snow "dumps," as soon as there are sufficient fish in the mesh to spring the trigger.

Roughly these automatic nets resemble the old-fashioned balance pole at the well, and work on the same principle, except that they are self-operating.

At one end of these balance poles is placed a heavy weight of perhaps two hundred and fifty or three hundred pounds. The other end holds the net. It requires three men to force down the net end and lock the trigger. After that the net is spread in the water and a trigger string run from the pointed iron pin that holds the catch of the pole to the "waist-line" of the net—a small line that completely encircles the net. When a sufficient catch has entered the net to put a strain on this waist-line the trigger string is tightened and the trigger pin jerked loose.

This releases the weighted end of the pole and lifts the net and its fish clear of the water. The pole works on a screw pivot which makes a half turn so that the net, when raised to the full height of the pole, is clear of the "shaft," or fishing hole.

When the weighted portion of the pole reaches its base it springs the trigger that releases the purse line and empties the fish into the snow.

As soon as this is done the net men force down the pole again, adjust the trigger pin and set the purse line—after which the net is ready to resume its automatic fishing operations.

The fish are then loaded on the sleds and hauled to the shipping points.

If they are for local consumption they are forwarded to destination without further preparation, usually being loaded into cars like so much cordwood.

Those that are for shipment to the States for immediate consumption in cold climates are usually bundled up in 100 pound packages and wrapped with sacking.

But those which are to be shipped to the big central markets demand more attention. They are packed in snow-lined boxes of standard size and transported to the big cold storage plants, where they are often kept until the middle of the summer.

As soon as these boxes of fish are received by the cold storage plants they are opened and the contents, which are frozen into one solid piece, dipped in vats of cold running water. The intense cold of the fish freezes the water so applied into a thin coat of ice, which makes them absolutely air tight and less likely to thaw. This is known as "glazing."

Another way of protecting fish packed in this way is to spray the boxes with water right in the freezers, forming an ice coat over the entire pile.

From these central markets the boxes of frozen fish are often loaded into refrigerator cars and shipped to the Southern states, to points where the climate would thaw and decay them were they shipped without protection of any kind.

Usually, however, these fish are kept in storage until the

*Reprinted from the *Illustrated World.*

market is "ready" for them—which means, until they will bring the highest price.

But there are millions of people in this country living in states where the climate will permit frozen fish to be handled like so much cordwood during three or four months a year—at ten cents a pound.

For several years the United States Bureau of Fisheries has been drilling away at the general public, trying to convince them of the fact that frozen fish is a decidedly first-class product, and that it is practically equal to fresh fish in every respect.

Yet fresh fish costs approximately five times as much as the frozen product. This, however, does not prevent ten pounds of fresh fish from going over the counter to every pound of frozen fish.

Last year the cold storage plants of the United States reported a total of approximately ten million pounds of frozen fish in their warehouses; or 1/10 of one pound per capita for our country.

During the winter months one pays about forty cents a pound for fresh fish, whereas in a frozen state this food can be profitably sold for ten cents a pound.

A few years ago frozen fish of the finest quality—bass, pickerel, pike, whitefish, etc.—were sold throughout Minnesota and North Dakota for about five cents a pound. These fish were peddled during the winter months from house to house in open wagons and when purchased could be stored in the woodshed or "leanto" until needed for cooking. In short, they would keep until the cold weather moderated.

Wherever there is cold weather frozen fish can be shipped safely with as little attention as a shipment of sand or stone would receive, or as a car of cordwood—for it is on a cordwood basis that this product is handled.

There are perhaps ten thousand lakes in the northern states that can produce winter-caught fish.

Winter-caught fish were first put on the market in a big way by the fishing interests of the Canadian Great Lakes, of Lakes Manitoba, Winnipeg and Winnipegosis.

As the industry grew hundreds of fishermen flocked to the ice fields of the three big Canadian lakes and pushed on to the waters of the interior to the north. Then a large railway hotel system sent fishing crews out into the wilderness to secure fish for its various hostelries. Soon hundreds of lakes throughout Canada and the Northern States of our country were being "winter-fished."

During the present season it is estimated that the catch will run to over a hundred and fifty million pounds for Canada and the United States.

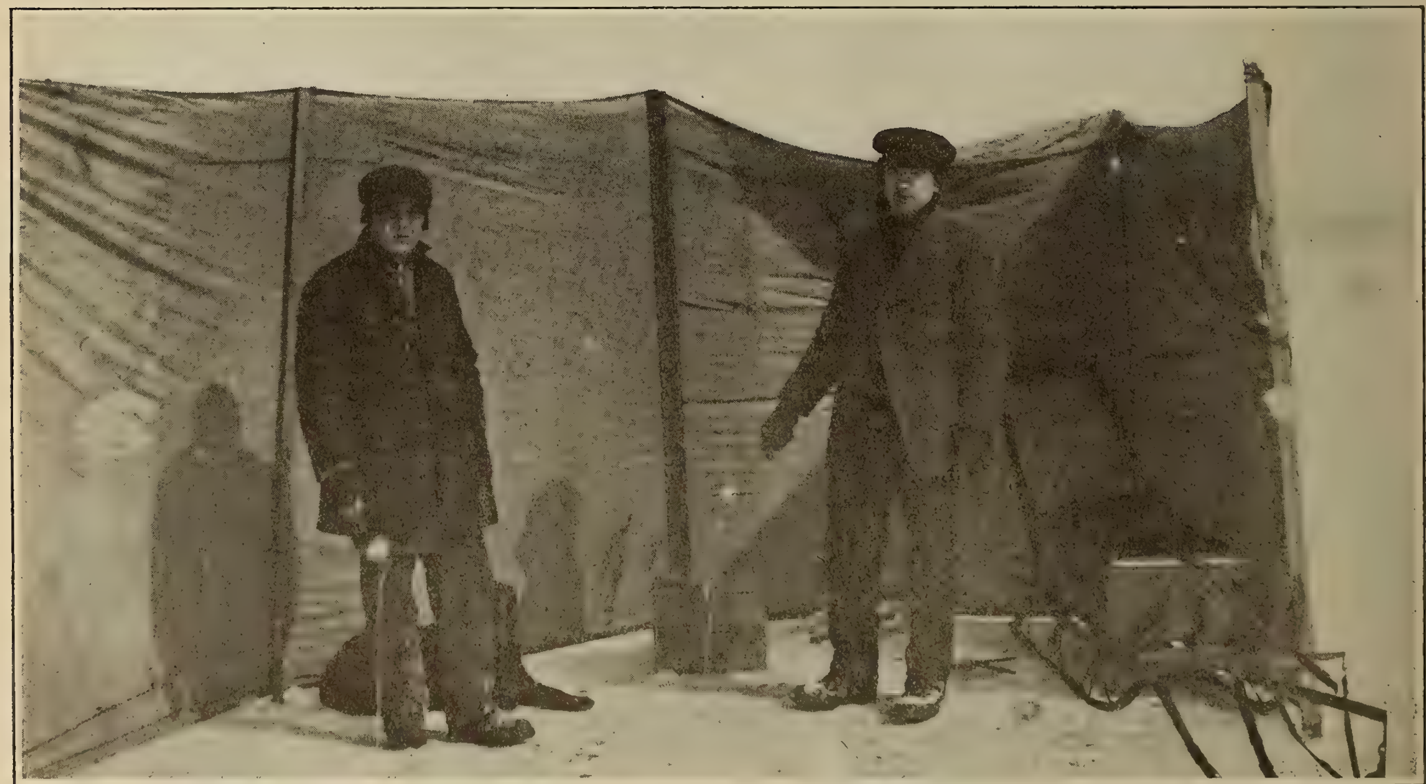
OZONE EXPLOSIVES.

The war gave a powerful impulse to chemical research in explosive substances and combinations, with the result that several new explosives of great power were adopted to meet new requirements. Some of these will rmain for use in the mining industry and the excavation work of engineering undertakings. The tendency is to get stronger explosives, with a view to lessening manual labor.

Progress seems to lie in the direction of using ozone as the oxidizing agent. In the combination of ozone with one of the aromatic series of substances, as, for example, ethyleozonide, or benzol-tré-ozonide, the so-called ozo-benzol, it releases enormous explosive energy. One kilogram develops an explosion some 2,000 calories, that is, 500 more than nitro-glycerine.

Ozo-benzol not only possesses this enormous energy, but its rate of detonation is exceedingly high, which gives it exceptionally great disruptive power. In this compound endothermic and exothermic reactions unite to bring about its characteristic shattering effects. Oxygen endowed with endothermic energy in the form of ozone combines with hydrogen, under conditions which give the maximum of power, to form the most violently disruptive explosive yet known. With our present knowledge, however, it is rather an indication of the direction in which an advance may be made than a particularly usable explosive.

A. Stettbacher, in a recent address to the members of the Swiss Chemical Society at Zurich, directed attention to another substance, chloric acid, which, like ozone, is of an endothermic and oxidizing nature, and may be used as the active element in an explosive. According to this authority, glycerine tri-chlorate liberates more than 3,000 calories—twice as much as nitro-glycerine.—*Technische Blatt*, June 14, 1919.



ADJUSTING LINES THROUGH HOLES IN THE ICE. NOTE THE CANVAS WIND SHIELD SET UP TO PROTECT THE FISHERMEN

Power and Speed of Steamers*

Various Resistances That Must Be Overcome

By Arthur R. Liddell

THE experimental tank has done and is doing much towards the solution of the question of the most advantageous forms and proportions of ships in relation to propulsive efficiency. For a given design experimental tests of a rather large number of models bring out relatively favorable conditions. But the process is a protracted and expensive one, and its completion leaves us uncertain whether a still better result could not be attained by further variations in the conditions. The reason of this uncertainty is that the ship's way is opposed, not by one force, but by a number of different resistances which do not always act together. The conditions in a given case may be favorable for the overcoming of one or more of these resistances, but not of the rest. Why the conditions are favorable or otherwise in such cases is not evident on the face of things, and cannot be clearly understood till the different resistances are analyzed separately and estimated as nearly as possible by mathematical means. The reason this analysis is not made is that the large number of unknowns in the problem makes the chances of a successful solution appear too slender. In approaching a task of the kind it is necessary to begin with a number of hypotheses and see where they lead.

The writer of this article obtained from a foreign publication the trial trip particulars of a number of vessels built by a certain firm of shipbuilders. An examination of these particulars led him to adopt certain hypotheses, not all of which will be regarded as orthodox, but which seem to promise tangible results.

The resistances experienced by a ship may be divided into those of:—

(1) Skin friction.

(2) Longitudinal component of excess water pressure on entrance.

(3) Longitudinal component (+ or —) of pressure of echo train—from entrance excess pressure—on run.

(4) Longitudinal component of under-pressure of water on run.

In addition, the propulsive efficiency of the whole installation of ship and motor is further affected by:—

(5) An excess or diminution of pressure of water in way of propeller occasioned by the echoes from the excess entrance pressure.

(6) A like excess or diminution of pressure occasioned by the echo or echoes of the run-wave pressure diminution.

(7) The degree of pressure in the water about the propeller due to the head of water, say, above its center of effort.

With regard to (1) the well-known Froude method of calculation gives results as accurate as can be hoped for at present; (2) has often been dealt with on the assumption that the extra pressure of the water on every vertical frame space of a wedge-shaped entrance is the same, but the results thus obtained have never quite squared with practice. In reality the pressure on any given frame space thus calculated is increased by accumulations of pressure from the frame spaces in front of it, and all these pressures progress sternwards in undulations of gradually diminishing mean intensities. The relative degrees of pressure on successive frame spaces along the entrance can be determined either by mathematical or by graphical means and be set up as ordinates of a curve which starting from zero at the stem, rises in mound-like form to a maximum at half-way length, and when the entrance has the length of a wave, as expressed by knots^2 $\times$ .5625, falls to zero again at the after end of the entrance. When the entrance is shorter than a wave length a roughly triangular bit of the after end of the curve is cut off. When the entrance is longer than the wave length the curve falls to zero at the after end of the wave length and then begins to rise again, assuming always that the entrance is truly wedge shaped. The actual entrance is, of course, not so, but the assumption of an equivalent wedge will help towards the solution in principle of the problem. The excess pressure intensities represented by the mound—or mounds—undulate sternwards like the familiar surface waves from the entrance. Each culmination of the undulatory line will be distant from the center of gravity of the original entrance excess pressure mound by a multiple—once, twice, three times, etc., of the length of the wave due to speed. The positions of the entrance wave pressure echoes along the run may be such as to produce excesses or diminutions of the ship's resistance, which, however, are less considerable in amount than was at one time believed. An allowance can be made for them.

Less readily accepted than the foregoing propositions will be that concerning the effects due to the position of the pressure echoes in relation to the propeller. Evidence of these effects may be seen in the fact that the lengthening of a ship often increases her propulsive efficiency—in fact, enables an increased displacement to be driven at a greater speed than before with the same engines. If we may assume the propulsive efficiency as proportional to degree of pressure in the water that the propeller lays hold of the phenomenon is at once explained. But we are then logically brought to the conclusion that the longitudinal position of the echoes from the under-pressure run-depression in relation to the propeller and the head of water above the center of effort of the propeller exert similar influence. Here we are met by the orthodox people who tell us that Beaufoy himself proved that the resistance of a fishlike body to propulsion through water is independent of its depth below the surface. Unfortunately, Beaufoy's writings are accessible only to the few, and even those few are not cognizant of all the conditions under which his experiments were made. No doubt some of his experiments have been repeated by subsequent investigators, but the resistances of the bodies experimented with would be mainly those due to skin friction, a subject our studies of which have not yet gone deep enough.

Very valuable as the Froude investigations and the system of estimating based on them have proved, they "get there" by short cuts. Every imaginable surface is studded with minute projections—visible with the aid of the microscope. A surface attended with very small friction is that of the fish, which is studded with regularly spaced scales or little hillocks with hollows between. Assuming degrees of pressure due to speed and to head of water respectively to play their part in the resistance, we may expect that at the higher speeds the water at the tops of the hillocks will be subject to higher pressures than that in the hollows, and that at very high speeds the hollows may even be denuded of water altogether. In the first case a small part of the surface would be associated with increased and the rest with decreased frictional resistance. In the second case only the smaller part of the surface would be in question at all. As regards head of water, the case does not seem so clear. It looks as though the area of the effective surface would increase with the head, but it may also be that the velocity of gliding of the water over the surface at the same time decreases sternwards at a quicker rate, so that the mean value of the expression area in square feet $\times$ (knots) 1.825 for a given length of surface remains comparatively unaltered.

The subject of surface friction needs much more thorough-

*From *The Engineer* (London).

going investigation than it has hitherto received, and, in view of the great possibilities involved, it is more than surprising that such scant consideration has been given to it. Doubtless minute quantities of oil exuded from the scales play a large part in reducing the resistance of the fish, but we may expect the nature of the ups and downs of the surface to be no less important.

With regard to the propeller, one effect that we might expect from an increase of its depth of immersion would be that cavitation would set in later, because the water would follow the retreating blades the more quickly the greater the pressure under which it stood. The known fact that a better result is given by a propeller working below the level of the keel than by one in the ordinary position is usually explained by the freedom of the water there from disturbance. People who think thus fail to realize that the wake disturbance caused by the passage of a ship must extend considerably below the keel—probably nearly as far as to the sides. In shallow water this below-keel part of the wake is interfered with by the ground. The forward motion of the wake is retarded and the echoes—pressure variations—deflected sternwards affect the propulsive efficiency favorably or the reverse according as zones of increased or of diminished pressure happen to be diverted to the propeller. These effects, of course, vary with the distance down of the surface of the ground. That a ship's deep-water speed is sometimes exceeded and sometimes not attained in shallow water is explicable only on some such hypothesis.

The question of the run pressure wave depression and its echoes is more complicated than that of the entrance pressure wave system. The speed of travelling of the ship past the particles of water in way of the run is retarded by the forward movement of the wake, and a part of it is accelerated again by the action of the propeller. It thus becomes a question what speed in knots must be assumed in the expression $\text{knots}^2 \times .5625$ for the length of the run wave. It seems probable that the length of the resultant wave length, if it may be so called, is about the same as that of the entrance wave, but that it is so cannot be taken for granted without further investigation. The actual results of the speed trials above-mentioned have been found to agree surprisingly well with calculations made on the basis of the assumptions of this article, and the principles enunciated may be earnestly commended to the notice of tank experimenters and others in a better position than the writer to pursue the necessary further studies.

The distance of the center of gravity of the entrance pressure mound from the stem may be taken roughly at one-quarter of the sum of the actual length of entrance and of the wave length due to the speed. Similarly the distance of the center of gravity of the run pressure wave from the fore end of the run may be taken at about one-quarter of the sum of the actual length of the run and of the length of the pressure wave due to the resultant speed of gliding of the water past the run. If we now take the longitudinal position of the center of gravity of the entrance pressure mound as that of the first, or parent, culmination and set off a train of wave echoes sternwards there will be inncreased or decreased pressure in the water about the propeller more or less pronounced according as the distance from the center of gravity is more nearly a multiple, or more nearly a multiple $+ \frac{1}{2}$, of the wave length due to the speed of the vessel. In connection with the run wave a similar influence is at work. The under pressure about the center of gravity of the run depression changes into increase of pressure, the maximum intensity of which will be at a distance of half a run wave length further astern. In good examples of single-screw ships the propeller will be at more than quarter-wave length abaft the center of gravity of the run depression, where the undulating pressure curve has risen to the upper side of its base line. Side screws that are arranged forward of the single-screw position tend to fall and usually do fall within the zone of decreased pressure of the run wave and as a consequence the loss of propulsive efficiency associated with them results.

Sir William White called attention in his "Manual" to the remarkably small difference in the powers for a given speed needed by a vessel in her light and loaded conditions respectively. The smallness of this difference is largely due to the circumstance that the friction producing surface increases more slowly than the displacement, but the difference is greater than this circumstance will account for. The deeper immersion at the same time increases the head resistance and its subsidiary pressure disturbances by large amounts which cannot by any system of theorizing be got rid of. If we first make fair positive and negative allowances for these influences and then take propulsive efficiency in proportion to depth below water surface of the center of propulsive effort of the propeller, we find the resulting power speed conditions for the two draughts to agree fairly well with each other.

In order to determine the proportions of power required to overcome the different resistances the following assumptions have been made:—The extra pressure on a small flat plate moving forward at a small angle with the line of advance is proportional to the sine and nearly proportional to the tangent of the angle. The longitudinal component of this pressure is nearly proportional to the square of the tangent. For an entrance of wave length and wedge shape the head resistance would be proportional to $\text{mid area} \times \tan^2 \times \text{knots}^2$ if the pressures on the successive frame spaces did not tend to accumulate and undulate sternwards as shown above. The tendency of the sternward accumulation may be taken into account by squaring the function of the resistance due to the obliquity so that $\tan^2$ would become $\tan^4$, and multiplying by length of entrance. This would give us $\frac{\text{mid area}^2}{\text{entrance}^3}$ in place of $\tan^2$ for a half-wedge of square section. But the half-wedge may not be square and it may be vertical or horizontal. In order to get a mean value of the tangent for these two propositions we may substitute $\frac{\text{mid area}}{\text{half-girth} \times \text{entrance}}$ for $\frac{\sqrt{\text{mid area}}}{\text{entrance}}$. The final expression for the head resistance then becomes $\frac{(\text{mid area})^5 \times \text{knots}^2}{(\text{half-girth})^4 \times \text{entrance}^3 \times \text{const.}}$, which, if not quite satisfactory, takes rough account of the conditions prevailing.

The expression for the over or under pressure at the propeller due to the echoes from the entrance pressure mound is represented by

$$\frac{(\sqrt{\text{mid area}})^4 \times 2 \times \text{knots}^2}{(\text{half-girth})^2 \times \text{entrance}}$$

$\times$ propeller disk area $\times$ a coefficient depending on the longitudinal position of the propeller along the undulation curve $\div$ a constant. It may be positive or negative according as the undulation curve sinks below or rises above its base line in way of the propeller.

The resistance or assistance of the entrance pressure wave echoes in way of the run may be taken account of by the addition or deduction of a percentage of the outcome of the expression for the entrance resistance. This will depend on the positions of the hills and hollows of the undulation along the run. Its amount is somewhat difficult to estimate, but is seldom very considerable. Until further investigation has thrown more light on the problem the resistance of the run depression has been taken as about the same as that of the entrance mound or at least to bear a certain constant relation to it. The expression for the over or under pressure at the propeller due to echo formation from the run under pressure will be the same in form as that given above for the over or under pressure due to echoes from the entrance mound, but the positive or negative coefficient may be much larger in this case, by reason of the shorter distance from source of pressure to propeller and consequent greater height of the undulations in question. Each successive undulation from a

source of over or under pressure appears to be half as high as the one before it.

The constants tentatively adopted in the calculations are $\frac{1}{1800}$ for the expression for the head resistance and $\frac{1}{1600}$ for the expressions representing the additions or deductions on account of pressure about the propeller set up by echoes from the entrance and the run. The center of effort of the propeller disk has been taken at one-third of its immersed height from the uppermost immersed part of it—from its upper edge when it is entirely immersed. In working, the results of the expressions representing the different sections of the resistance have been multiplied at once by the speed in knots instead of this being left to the final calculation. This, of course, is an optional matter.

TABLE A.

	Functions of powers to overcome the different parts of the resistance.					Constant immersion	Estimated I.H.P.	Actual I.H.P.
	1.	2, 3, and 4.	5.	6.	1 to 6.			
Light draught ..	451 +	26 +	19 −	57 −	401 +	$\frac{27}{9.83}$	1101	1173
Load draught ..	430 +	247 +	6 −	154 −	517 +	$\frac{27}{14.17}$	1055	1034

Table A gives an example of the application of the above system to a ship that was tried on the measured mile course both at light and at load draught.

For the light draught some addition must be made to allow for unfavorable conditions, such as that of incomplete immersion of the screw. For the load draught the conditions are better than the average of those of the trial trips dealt with, and the necessary deduction of 2 per cent does not seem excessive.

The best power speed conditions for a given speed and a given approximate length of ship are those in which the entrance and the run are each equal in length to the wave length due to the speed and in which the absolute length from the stem to the propeller is equal to a multiple of the wave length + ½. We may then draw up a table somewhat like Table B. This table can be expanded to any desired degree.

TABLE C.

Length from stem to propeller in wave lengths (W.L.)	Prismatic coefficient.
2½	.6
3½	.714
4½	.778
5½	.818

The prismatic coefficients corresponding with advantageous lengths of entrance and run are given in Table C.

The ballast draught corresponding with a given length may be obtained approximately from the equation draught $= \sqrt{\text{length}} \times C$, in which the constant C will usually lie between .75 and .9. The load draught may be about one and a half times the ballast draught or $1\frac{1}{4}\sqrt{\text{length}}$. Table D. gives a number of illustrations of these proportions for different sizes of vessel.

Depth of vessel will be such as to keep the waves from coming over and provide a fairly "dry" ship. In general, the International Rules for Freeboard do this. Breadth of vessel will be such as to give a suitable degree of stability with the conditions of length, depth, and size and extent of erections already determined upon.

It often happens that other conditions of a given design outweigh those of propulsive efficiency. It may promote economy in other respects to make the length of a ship of given speed greater or less than as given in Table A. If a shorter length is required it will be good practice to lengthen the middle body by extending it so far forward that the longitudinal position of the center of gravity of the entrance pressure mound remains unaltered. Within reasonable limits the difference between the lengths of entrance and run thus arising will probably not be objectionable. For a longer length the middle body would have to be shortened and the entrance lengthened. Increase of breadth of a design will increase resistance in so far that it will make the angles of obliquity of the water lines less acute, but it would be a mistake to try to counteract this effect by a reduction of the prismatic coefficient, because the propulsive efficiency of the vessel would thereby be impaired. The increase of carrying capacity by which the increased resistance due to greater breadth would be accompanied might justify the addition to the horse-power required.

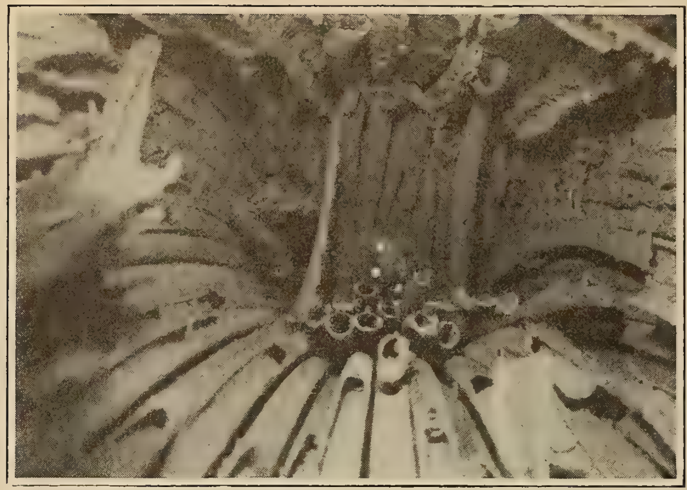
The proportion that breadth should bear to depth depends on conditions other than those of resistance, and its influence on the horse-power needed for a given speed must be taken as it comes. The power speed conditions discussed above are those of cargo vessels and passenger liners of not more than about two and a-half wave lengths in absolute length. Vessels of less than two and a-half wave lengths are beyond the range of the above-named particulars of actual trials, but the effects of wave action may be seen in their performances. Their lengths of entrance and run are each less than that of a wave length due to speed of vessel. The distance from center of gravity of entrance wave to propeller will, with increase of relative speed, soon become less than a wave length. A vessel of one wave length in absolute length will work at a grave disadvantage as regards each of the parts 2 to 6 of the resistance given in Table A. If the vessel be driven at a much higher relative speed—say, at one in which her absolute length is equal to one-quarter of that of the wave length due to her speed—the conditions will in some respects improve. The propeller will then come within the first positive part of the echo from the entrance wave with good results to the propulsive efficiency. The echo from the run wave will carry the under pressure sternward to the propeller and beyond it, with consequent detriment to the propulsive efficiency. At infinitely great relative speed the first echo would carry the entrance pressure almost unchanged to the run and practically balance it, so that the parts 2 and 3 of the resistance would be avoided. The run depression would be carried sternwards unabated beyond the propeller. There would be a certain degree of over-pressure in way of the propeller, making for propulsive efficiency. The squat experienced in a vessel of relatively very high speed is due to difference between the pressure in the water in way of the entrance and that in way of the run. This fact throws light on some experiments carried out with a torpedo boat by Mr. Yarrow. At low speeds the boat went slightly down by the head. As the speed increased this trim changed in succession to those of even keel, slight squat, deep squat, and slight squat growing less with increase of speed.

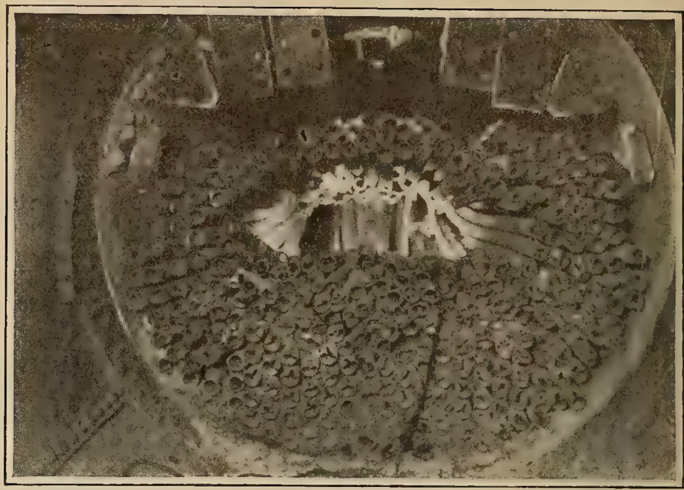
TABLE D.

Length. Ft.	Ballast draught. Ft. in. Ft. in.	Load draught. Ft. in.
100	7 6 to 9 0	12 6
225	10 9 to 13 6	18 9
400	15 0 to 18 0	25 0
625	18 9 to 22 6	31 3
900	22 6 to 27 0	37 6

TABLE B.

Speed in knots.	Length of entrance (= length of run) = wave length (W.L.) in ft.	Advantageous length from stem to propeller.							
		In W.L.	In feet.	In W.L.	In feet.	In W.L.	In feet.	In W.L.	In feet.
10	56.25	2½	140	3½	197	4½	253	5½	310
11	68.06	2½	170	3½	238	4½	306	5½	374
12	81	2½	202	3½	283	4½	364	5½	445
13	95.06	2½	238	3½	333	4½	428	5½	523
14	110.25	2½	276	3½	386	4½	496	5½	606
15	126.56	2½	316	3½	443	4½	570	5½	696





Courtesy of Railway and Locomotive Engineering.

EFFECTS OF SPONTANEOUS COMBUSTION ON THE BOILERS AND FLUES OF A LOCOMOTIVE

A Curious Case of Spontaneous Combustion*

Boiler Tubes of a Locomotive Consumed After the Fire Was Withdrawn

OCCASIONALLY the impossible seems to happen in the mechanical and chemical world and not the least of these impossible paradoxes is the burning of tubes by a seemingly spontaneous combustion, which is reported from time to time.

Here is an illustration of what is meant:

A locomotive was in an accident and was side-swiped. The running board, cab, brackets and main reservoir were torn off from the left side, the guide yoke bent and other minor damages inflicted. Some of the studs holding the running board were also torn out of the boiler, which caused a loss of steam and water. This happened about 12:30 at night. The fire was knocked out of the engine as quickly as possible, the dampers closed and the night roundhouse foreman notified.

At 2 o'clock in the morning the roundhouse foreman went out to the yard and, finding the fire out of the engine, ordered it hauled into the roundhouse. This was done at about 3:30, when it was set in over the cinder pit. Shortly afterwards one of the laborers at the cinder pit came to the foreman and notified him that the headlight had exploded. He went to the engine at once and found the front red hot, which was the cause of the explosion of the headlight. He then took off the small front and found everything red hot inside. The next step was to spark the front end and remove the brick arch, but that did not seem to relieve the heat. To help in the cooling off a plate was put over the top of the stack, and the firebox door opened.

At 6 o'clock in the morning the front end was still very hot, though there was no fire in the firebox or ashpan and the brick arch had been removed. The men were afraid to put water in the front end because of the uncertainty as to what would happen. At noon, or about twelve hours after the accident and ten hours after the fire had been hauled the flues were still red hot in the engine. A part of the tube sheet had been melted as well as the ends of many of the tubes, and the metal had run down into a puddle in the front end.

When the engine was critically examined after it had cooled off, it was found that the greatest destruction was wrought by the heat, just back of the injector check where a large number of tubes were melted.

The illustrations show the condition of the tubes after the removal of the front tube sheet and of the tubes in the interior of the boiler.

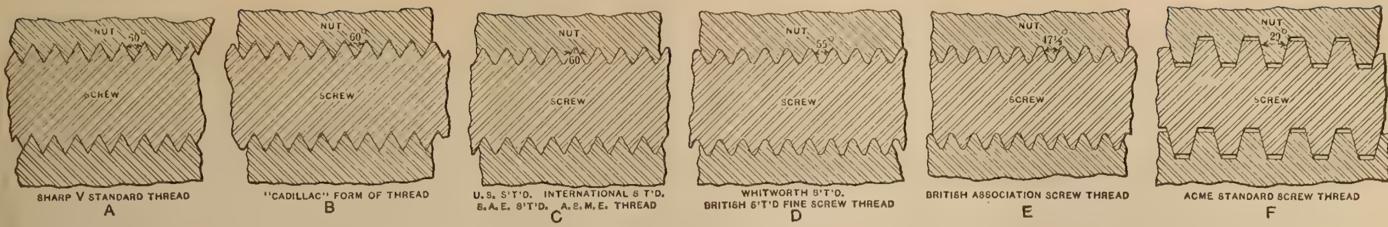
Unfortunately we have no data regarding the exact condition of the tubes in the boiler under consideration, or of those in the pile over the fire, and supposititious case must be built up in order to arive at a possible explanation of the phenomenon before us.

It seems fair to assume that the outside or water side of the tubes was covered with scale, because it is known that the boiler was using a scale-forming water. This insures a certain amount of insulation against radiation of heat from the outer surface of the tubes both by the coating of scale and the quiet air confined in the boiler. It is also assumed that the interior or fire side of the tubes was coated with rust and soot, and that there were some unburned cinders lying in the bottom; though of this there is no direct evidence. It is merely essential to the construction of the case.

Finally we know that there was a brick arch which was hot at the time of the accident and that the ashpan dampers were closed when the heat was developed in the boiler.

Then, with a little air leaking through the dampers, there was a gentle and quite imperceptible movement of hot air through the tubes to the stack, the air having been heated to a high temperature by its contact with the arch. As the water was out of the boiler, and the tubes were fairly well protected against a loss of heat, the air was not appreciably cooled in its passage through the tubes and the latter were heated. *This heated air coming in contact with the iron rust, or oxide of iron, broke it down, and, by so doing, released an excess of oxygen into the air.* This promptly, under the influence of the heat, proceeded to form a new compound with the available carbon, which developed a still further increase of temperature, producing more oxygen, which was immediately available for combustion and which was thus fed without the need of a supply of oxygen from the air. It is merely a simple cycle and quite within the bounds of possibility, and is offered as an explanation of an occurrence that seemed uncanny because it fell outside the range of our ordinary everyday experience. It might have happened from that cause, and the reason it does not happen oftener is that the necessary conditions are not present. There must be an empty boiler so that the tubes and contained air may not be cooled by the surrounding water. The contained air must be nearly stagnant. There must be a source of heat of such a character as not to create a draft and the outer air must be excluded. And there must be present a sufficient quantity of the oxide of iron to supply the needed excess of oxygen, and there must be the carbon to unite with it when it is set free. All these unusual conditions are necessary to the execution of the hypothesis, but when they do exist, there is no reason why the unusual phenomenon here chronicled should not manifest itself.

*Abstracted from *Railway and Locomotive Engineering.*



Courtesy of "Machinery"

FIG. 1. COMPARATIVE FORMS OF VARIOUS STANDARD SCREW THREADS

Standards for Screw Threads

Can a Universal and International System Be Evolved?

By Herbert T. Wade

THE recent war, requiring as it did interchangeability and standardization of military matériel to an extent never before realized, brought distinctly before the civilized nations of the world the importance of international standards. This matter was not settled by the conclusion of the war, but becomes even more important, as a vastly increased international commerce unquestionably will bring to the fore the matter of international commercial standards in many classes of articles and materials. It is inevitable that the markets of the world will be available as never before, and with improved transportation facilities business will come to those that meet the conditions of demand and have their commodities most highly standardized according to some predominant or universal system.

The decision of the United States to avail itself of French and British ordnance and other appliances, as well as manufacture them from their designs, emphasizes the question of standards for various parts, especially screw threads, bolts, nuts, etc., and in the manufacture of vast amounts of equipment by a large number of establishments there was involved securing interchangeability of parts in a marked degree and the use of screw thread systems quite foreign to American mechanical practice.

There was no such thing as a universal or international standard, for in each leading mechanical country of the world, speaking broadly, different standards of screw threads are employed, and in some cases several standards, so that independent of international standards today locally various attempts at standardization have been or are being made. Furthermore the question, while intimately connected with fundamental standards of length, such as those of the Anglo-Saxon and the International Metric Standards, is at the same time quite apart from them, inasmuch as there are different screw thread standards among the countries using each set of measures, and in some cases several standards in the same country. Consequently it would seem that some approach to a single internantional standard is most desirable so that a reasonable degree of interchangeability in tools and parts con be secured, and it is believed that international commerce, and especially commerce in machinery, machine tools and machine hardware would be promoted by such a policy. If there were any single standard to which all countries might conform, the subject would be comparatively simple; but in every country in the last ten years there have been attempts at greater standardization and more perfect standards and systems. Today there are both national and international commissions investigating this matter, so that a consideration of the various systems now in use based on important work done at the U. S. Bureau of Standards is timely and interesting.

So content are people to take for granted reasonably good or at least serviceable systems of standardization in a single country or in a single industry, that often they are apt to neglect the consideration of earlier conditions and at the same time the necessity for still greater improvements. When it is recalled that a freight car can be coupled in any train on any railway in the United States or Canada, and can at the same time be repaired in any shop, it seems difficult to realize that at one time such a condition of affairs was practically non-existent. Today there is the added incentive to standardization that many of the standards used in single nations intrinsically are subject to improvement, and if they are to be improved it is fair to ask that they should also conform at the same time to other and better standards, and should be applicable throughout the entire civilized world. The task that is before engineers, bureaus of standards, physical laboratories, and like institutions, is most apparent, and engineering commissions with varying objects are now working on this subject.

In all of this work the matter of the screw thread is fundamental, as the screw in one form or other enters into practically all machine design, construction and operation. It must be invariable and readily reproduced with high precision by ordinary commercial shop methods of manufacture. On a standard system of screw thread and sizes naturally depend all bolts, nuts, taps, dies, couplings, and the

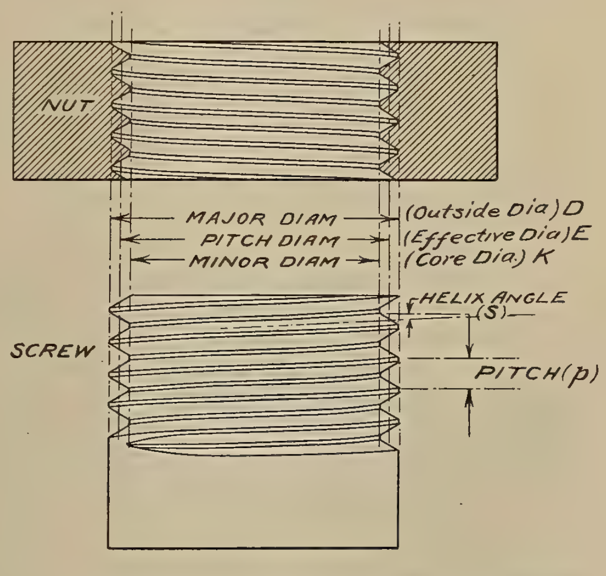


FIG. 2. NUT AND SCREW INDICATING DIAMETERS AS EXPRESSED IN CONVENTIONAL DEFINITIONS

various materials of construction such as pipe which must be purchased in open markets and found within certain limits absolutely interchangeable. In common language they must "fit"; such articles, therefore figure in ordinary

commerce. Now in any consideration of the question of the screw thread, it is desirable to appreciate the various elements and to understand precisely what is involved, including the very important difference in different systems. The accompanying diagrams, show these elements, and it may be

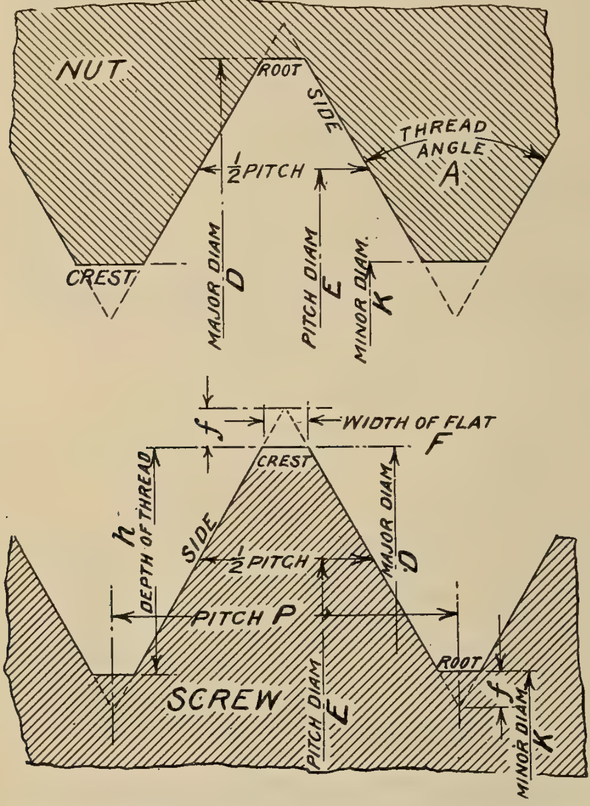


FIG 3. ESSENTIAL ELEMENTS OF SCREW AND NUT WITH CONVENTIONAL TERMINOLOGY AND SYMBOLS

advantageous to reproduce the definitions applicable as recommended by the United States Bureau of Standards. Considering a screw thread, we can define *outside diameter* as the diameter on the outside of the thread, in other words, the external or full diameter. In screw thread formulas as used by the U. S. Bureau of Standards, this is indicated by the letter D. The *root* or *core diameter*, indicated by K, is the smallest diameter, whether for a screw or a nut, while the *pitch diameter*, indicated by E, is defined as the diameter of a screw at a point midway of the depth of the thread equal to the outside diameter, less the depth of one thread, varying in amount for different types of thread. The *top* or *crest* of the thread, or *flat* as it is known in the U. S. Standard Thread, requires no definition, while the *root* is the bottom surface joining the sides of two adjacent threads, whether in screw or nut. The *angle of thread*, expressed by A, is the total or included angle between the sides or slopes of a thread in a plane passing through the axis of the screw or nut. The *slope* of the thread is the angular part which connects the large and small diameters of the thread. The *pitch* (P) is the distance from a given point on one thread to a similar point on the next thread along the axis of the screw, the distance from center to center of two adjacent threads being taken. In a single thread screw this is sometimes called the *lead* which is properly however the longitudinal distance traveled by the screw in one turn. The pitch is also the reciprocal of the number of threads (N) per inch or other linear standard. With these terms understood from the definitions and reference to the diagrams, it is possible to consider the various important screw thread systems now in use and show how they differ and how they might be unified in a single system.

Theoretically in order that screws should be interchangeable both as regards nuts and as regards each other it is necessary that certain of the essential elements named above should be accurate in both screw and nut, but various modifications of a theoretical thread have been made that reduce the number of essential elements where accuracy is necessary for proper fit and interchangeability of screw and nut. For each of the systems described below tolerances either official or more or less accepted in general practice have been worked out and followed to a greater or less extent. In some cases by a slight change as in the diameter of the bolt or nut of certain sizes of screws interchangeability is secured between different systems as the British Whitworth and the U. S. Standard, as illustrated in the accompanying diagram. (Fig. 4.) For various sizes where the pitches are the same the necessary modifications in the effective diameter to secure a satisfactory fit have been calculated.

The British Standard Whitworth Screw Thread was first proposed in 1841 by Sir Joseph Whitworth in a paper read before the Institution of Civil Engineers of Great Britain. The aim of this engineer was to represent so far as thread angle, diameters and pitches were concerned the average engineering practice in England at that time. Sir Joseph Whitworth is quoted as saying: "The mean of the angle in 1-inch screws was found to be about 55°, which was also nearly the mean in screws of different diameters. Hence it is adopted throughout the scale." The profile of the Whitworth thread, which became standard for Great Britain and wherever British machinery was exported, is shown in the accompanying diagram, and in order to make the accepted practice definitely standard, the British Engineering Standards Committee in 1905 adopted the standard Whitworth system, and in a report formulated the dimensions of a system. In this report it is stated: "In the Whitworth form of thread the angle between the slopes measured in the axial planes is 55°, the threads are rounded equally at crests and root to a radius of 0.137329 times the pitch, and therefore the depth of the thread is 0.640327 times the pitch." In other words, one-sixth the height of the basic triangle is cut off from the crest of the thread, and one-sixth the height is filled in at the

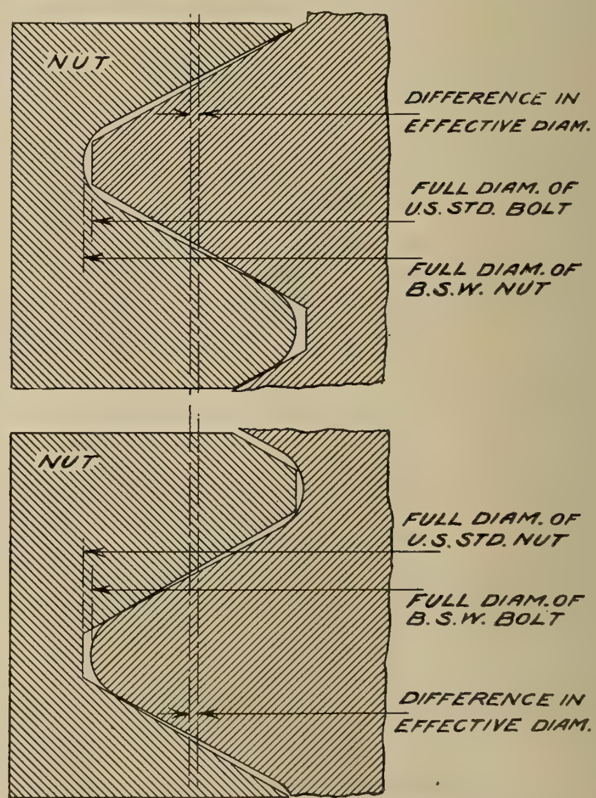


FIG. 4. SECURING INTERCHANGEABILITY BETWEEN U. S. STANDARD AND BRITISH STANDARD WHITWORTH THREADS

By slightly modifying the effective diameter of either the U. S. or the Whitworth bolt or nut in pitches common to both systems it is possible to secure interchangeability without modifying the thread form of either.

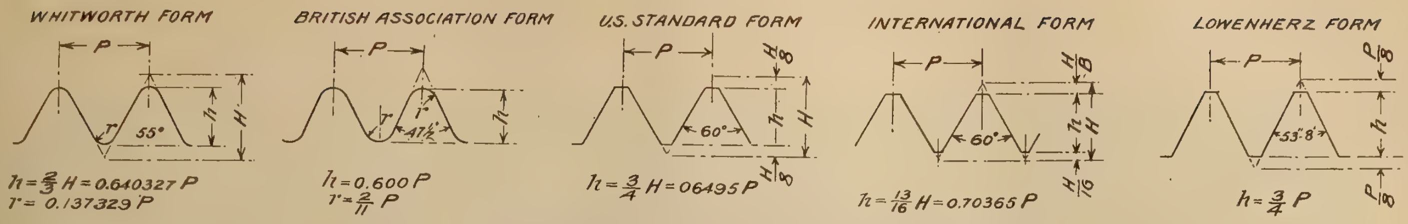


FIG. 5. COMPARISON OF FORMS OF STANDARD THREADS

root. On this system the British Engineering Standards Committee has worked out tables of tolerances for bolts and nuts with considerable elaboration. The Whitworth form of thread is employed for the British standard fine screw thread system, for the British standard pipe thread, and the British standard conduit thread.

The British standard fine screw thread system was recommended in 1905 in order to provide a series of fine pitches to supplement the Whitworth series employing the Whitworth form of thread. The pitches recommended are obtained by the formulas $P = 0.1 \times D^{2/3}$ for sizes up to and including 1 inch diameter, and by formula $P = 0.1 \times D^{5/8}$ for sizes above one inch.

The British standard pipe thread for iron and steel tubes was also adopted in 1905 by the Subcommittee on Screw Threads and linear gages of the British Engineering Standards Commission, and was approved by the main committee in March of that year. Two classes of screw connection were duly recognized by the committee and are now in use, namely, Class 1, the Taper Screw, and Class 2, the Parallel Screw. In Class 1 the screw at the pipe end is tapered 1/16 inch per inch of the length measured on the diameter. The screw in the coupler may be either straight or tapered. Commonly straight coupler and tapered pipe end are used, though conical couplers are used to secure exceptionally good fits. In Class 2 straight screws have the same diameters as the diameters of tapered screws at the gaging notch. The profile of the British Standard Taper Screw for pipe is shown in B of Fig. 8.

The British standard thread for steel conduit is of the Whitworth form, and as for pipes two classes of steel conduit are recognized as standard: Class A, Plain, and Class B, Screwed. In Class A, which is a light gage conduit, neither the ends of the conduit nor the sockets adjoining the lengths are threaded, but in Class B, which is a heavy gage conduit, both of the ends are threaded with the Whitworth form of thread as defined for British standard pipe threads.

Inasmuch as American mechanical engineers employ the same linear standards as the British, it is desirable next to consider the U. S. Standard Screw Threads, which vary from the Whitworth in many important particulars. This thread was also known as the Franklin Institute or Sellers Thread, from the fact that it was proposed by Mr. William Sellers in a paper read before the Franklin Institute in 1864, and duly approved by a committee of the Institute in December of that year. It was adopted with slight modifications by the United States Navy Department and the Master Mechanics and Car Builders' Association, and it is on this standard that the very widespread standardization found in the United States has been carried on, by a formula where $N = \frac{16.64}{(15\,D + 10) - 2.909}$ where N equals the number of threads per inch and D the diameter in inches. As a result of this formula values for N are given which agree with the Whitworth pitches, except in two or three sizes.

Now referring to the diagram showing the U. S. Standard Screw Threads, the difference between it and the Whitworth is most apparent in the thread angle, where 60° was selected in place of 55°. Mr. Sellers stated his objections to the 55° angle as follows:

1. The angle of the 55° is difficult of verification.
2. The curve at the top and bottom of the screw will not fit the corresponding curve in the nut.
3. The increased costs and complications of cutting tools required to form this kind of thread in the lathe.

The angle of 60° was selected for two reasons, namely, that it could be reproduced and verified with greater ease, and secondly, because it was also in more general use in the United States. The Sellers system underwent slight modifications, and then became the United States Standard System, where the thread is flattened ⅛ the height of basic triangle at crest of thread and nominally filled in ⅛ the height at the root. The nominal depth of the thread then is 0.64952 times the pitch as is shown in the diagram Fig. 5.

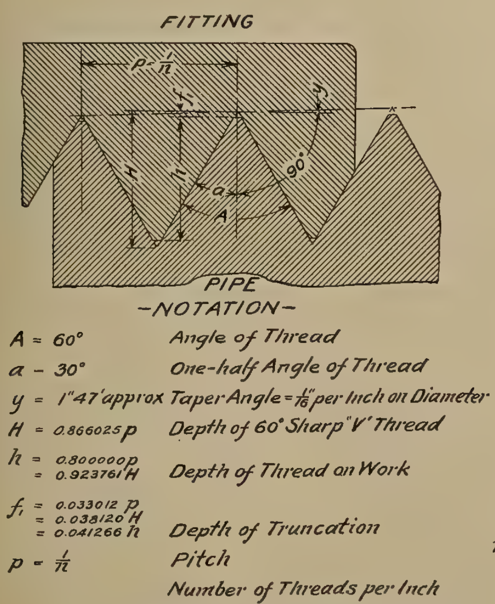


FIG. 6. AMERICAN BRIGGS STANDARD THREAD FORM

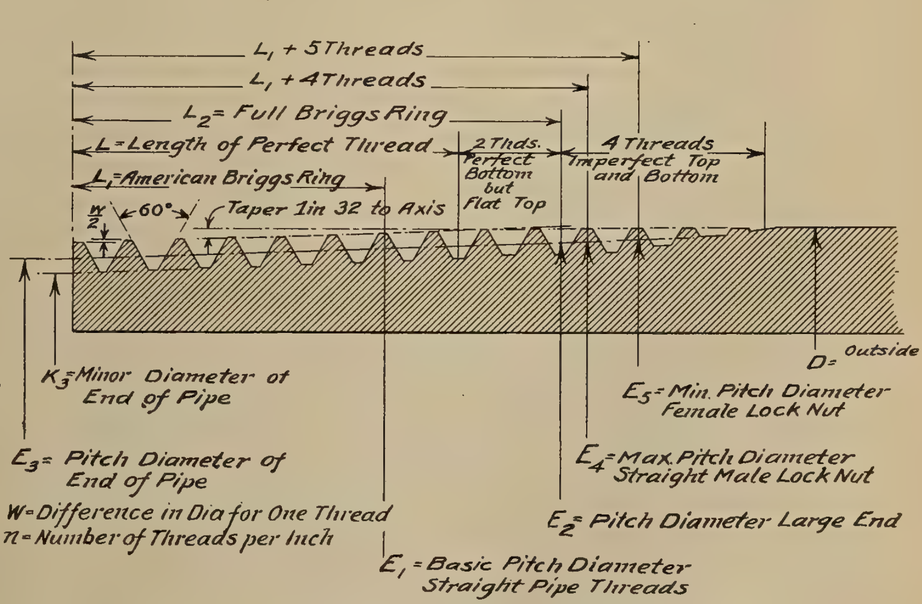


FIG. 7. U. S. NATIONAL TAPER AND STRAIGHT PIPE THREAD

In the United States the lack of interchangeability of small machine screws gradually became apparent, and in 1902 the American Society of Mechanical Engineers appointed a committee to report on the standard proportions for these screws. This report was duly formulated in 1907, and the committee recommended the A.S.M.E. Machine Screw Standard where the U. S. Standard form of thread was used and the pitches were a function of the diameter as expressed by the formula

$$\text{threads per inch} = \frac{6.5}{D + 0.02}.$$

With the development of machine work, and especially in the construction of automobiles, it was found that finer pitch screws were required than had figured in the U. S. Standard system, and accordingly the A.L.A.M. Fine Pitch Screw Thread System was developed for automobile work. In 1911 this system was revised and extended. The finer pitch screws were required for automobile work for two reasons: first, fine pitch screws and nuts do not work loose readily when subject to vibration; second, because of increased strength due to increased core diameter obtained, weight could be saved by using smaller screws. Previous objections to using threads of fine pitch that they were easily stripped or crossed in making up did not apply in automobile construction, because it was possible to specify and secure a good fit between nut and screw, and furthermore, it was possible to use a good grade of steel exclusively.

In March, 1918, the Society of Automotive Engineers proposed a system of still finer threads for special automobile work. The automobile industry, on account of the large number of machines manufactured in well equipped and special shops in many cases has employed special screws peculiar to a single manufacturer or organization.

In the United States, while the United States Standard is generally followed, and the 60 degrees angle in the profile, there are various modifications ranging from the sharp V standard, where thread and nut are supposed to fit accurately to special forms used by large manufacturers, examples of which are seen in motor car manufactories. For example, the so-called "Cadillac" form of thread, where the screw thread of the sharp V standard is modified at the crest, it is only necessary to consider the pitch diameter, pitch and angle of thread on the screw and the nut. These two types are shown in profile in A and B of Fig. 1.

The Acme Standard Screw Thread is found in American machine design and takes the place of the square thread, being an adaptation of the form of worm thread commonly employed. It is a little shallower than the worm thread, but the same depth as the square thread, and much stronger than the latter. The Acme thread has a clearance top and bottom, so that the principal consideration involved is the accuracy of the thread as regards the angular faces and its pitch and pitch diameter. The angle of the thread is 29 degrees as is shown in F of Fig. 1.

The width of point of tool for screw or top thread = (0.3707 ÷ No. of threads per inch) — 0.0052.

The width of screw or nut thread = 0.3707 + No. of threads per inch.

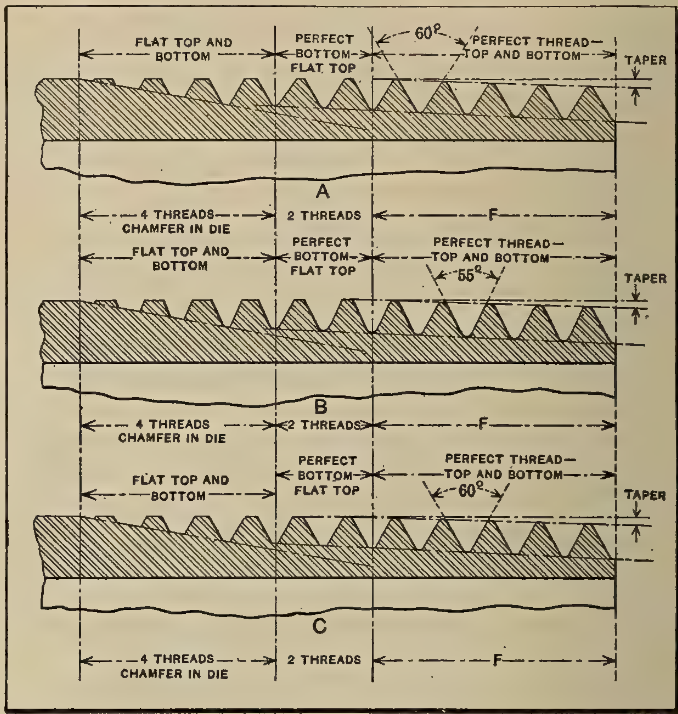
The diameter of Tap = Diameter of Screw + 0.020.

$$\begin{array}{l}\text{Diam. of Tap or:}\\ \text{Screw at Root:}\end{array} = \text{Diam. of Screw} - \frac{1}{\text{No. of Threads per in.}} + 0.020$$

$$\text{Depth of thread} = \left\{ 1 \div (2 \times \text{No. of Threads per in.}) \right\} + 0.010.$$

The Briggs Standard form of pipe thread is in common use in the United States and was adopted by the American Society of Mechanical Engineers, whose committee reported, recommending this system in 1886. The original Briggs Standard pipe thread has an included angle of 60°, and is slightly rounded at the top and bottom, so that the single depth of the thread, instead of being equal to the pitch times 0.866 inch is only 4/5 of the pitch, or equal to the pitch times 0.8 inch. The Briggs Standard is also made in a modified form resembling the U. S. Standard form of thread. The Briggs thread tapers with respect to the axis of 1 part in 32, or ¾ of an inch to the foot total taper. It is very obvious that absolute interchangeability obtained through accuracy of threads and standards is necessary in all mechanical and construction work. Pipe of various forms, together with couplings and other parts, must fit to the required degree of accuracy.

An early attempt to secure precision in screw threads was made in 1878, when the Horological Section of the Geneva Society of Arts recommended a system of screw threads designed by Professor M. Thury. This system was based on the metric standard and reproduced the measurement of well proportioned watch and small instrument screws then in actual use in European countries. The thread has an angle of 47½°, and is rounded at the crest with a radius of 1/6 p, and at the root with a radius of 1/5 P, giving a depth of thread of 0.6P. The various sizes were designated by consecutive numbers from No. 0 = 6 mm. diameter, 1 mm. pitch, to No. 25, 0.254 mm. diameter, 0.0178 mm. pitch. The pitch corresponding to any size number was expresed by the formula $P = 0.9^n$. The outside diameter corresponding to any pitch was expressed by the formula $D = 6$ times $P^{6/5}$. In 1884 the British Association for the Advancement of Science recommended the use of the Thury System with modifications for all screws below ¼ inch in diameter, and this system came into general use, particularly for instruments in scientific work. The modification in the thread form was designed to give equal rounding at crest and root of approximately 2/11 P. The British Engineering Standards Committee in their 1903 report on British Standard Screw Threads gave dimensions of screw threads in this system, including the recommended clearances between the crests and roots of the threads. This system is of interest, inasmuch as it has indicated the practical use in Great Britain of threads based on the Metric System, and no difficulty has been experienced in their use on small apparatus.



Courtesy of "Machinery"

FIG. 8. AMERICAN BRIGGS (A), BRITISH WHITWORTH (B), AND MODIFIED BRIGGS (C) PIPE THREADS

With the development of machine tools made according to the Metric System and the general use of the Metric System by the Continental countries, it was obvious that a metric screw thread standard for the larger sizes of screw threads should be adopted. The French Société d'Encouragement de l'Industrie Nationale in 1894 adopted a metric screw thread sys-

tem, and this was approved and adopted by an International Congress convened at Zurich in 1898, and representing the principal Continental countries. The profile of the screw thread is shown in Figures 1 and 5.

In both systems the form of thread had a 60° angle, and the crest of the thread was flattened ⅛ the height of the basic triangle, while the root was filled in 1/16 the height, thus affording a definite clearance between tops and bottoms of threads, and in the main following the profile of the Sellers Thread. The principal difference between the French and the International Systems was in the pitch of the 8, 9, and 12 mm. screws the French specifying 1 mm. and 1.5 mm. pitch respectively, while the International System had 1.25, 1.25 and 1.75 mm. The actual form at the root was left to the manufacturer.

Another important screw thread system used in Continental Europe was originally adopted in 1888 by the Verein Deutscher Ingenieure, and included screws of 6 to 40 mm. diameter inclusive. The thread selected had an angle of 53° 8″, and was flattened at the top and bottom ⅛ the height of the basic triangle, which naturally had a height equal to its base, therefore making a depth of thread ¾ the pitch. In 1893 a commission representing German instrument makers, technical societies and government departments adopted a system of threads ranging in diameter from 1 mm. to 10 mm., and especially intended for use in small machines and instruments. The same form of thread was employed as in the earlier system, and the overlapping sizes from 6 mm. to 10 mm. were identical. This system was called the Loewenherz System, after Dr. Leopold Loewenherz, at one time Director of the Physicalisch-Technischen-Reichs-Anstalt.

It will be apparent, therefore, that irrespective of the fundamental system of linear measures used, whether Anglo-Saxon or Metric, there was and is throughout the world a great diversity of threads, and this was distinctly apparent in the war in the manufacture of ordnance, especially when three countries with different mechanical practice and standards such as Great Britain, France and the United States were concerned in the common manufacture and use of ordnance matériel. In France various systems had been used even within the army, and it was decided during the war to adopt a standard artillery system of screw threads which was based in the main on the International system, modified, however, as was appropriate for ordnance. In the meantime much of the material had been made with various threads, including the Loewenherz Thread, and matériel made in the United States designed to be interchangeable with the French also employed the Loewenherz Thread, for which various gages were sent from France to America.

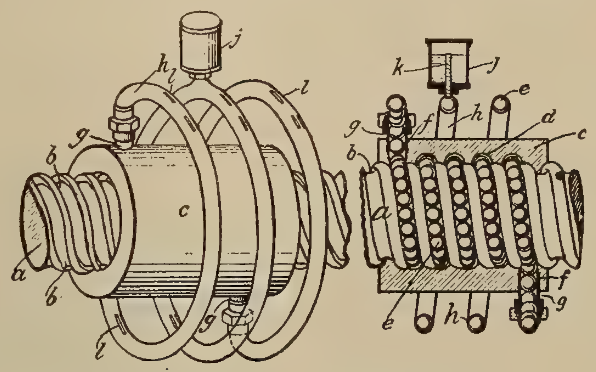
But aside from matters of war material, manufacturers and authorities in the United States and Great Britain, France, and other foreign countries, have been keenly alive to the industrial and commercial situation involved, and during the past year there has been considerable progress made toward international screw thread standardization, though little that is definite or actually accomplished can be recorded now. There have been numerous conferences between American and other national engineering commissions in regard to screw threads and pipe threads. In the opinion of the United States National Screw Thread Commission, which was established by Act of Congress approved July 18, 1918, and continued by a similar Act approved March 3, 1919, to ascertain and establish standards of screw threads for use of the Federal Government and in manufactures, such an international standard should be established by giving consideration to the predominating sizes and standards used in manufactured products, as well as to the possibilities of providing a means for producing this international screw thread by the use of either the English or the Metric System of measurement.

From the foregoing resumé the main points and the divergencies of the various screw threads can be appreciated, and it would not seem difficult to develop a common international system upon which the manufacturing countries could unite at least so far as goods or materials intended for foreign trade are concerned, which system at least could be specified when desired. While important work has been done lately for various national screw thread systems the undertaking will not be complete until one absolutely international standard is secured with proper definition and tolerances, so that with taps, dies, and lead screws arranged on an interchangeable basis all screw products could be reduced to a single system the world over.

ANTI-FRICTION NUT AND SCREW GEARING.*

The efficient cooling and lubricating of a long run of gearing is often overlooked until certain difficulties arise as to its running efficiency. An improved means of interest has recently been patented by Mr. F. L. Rapson, of Liverpool (patent specification, 131,475). It relates to anti-friction nut and screw gearing and particularly to gearing of the type in which a shaft or rod and a nut or block are formed with co-operating helical grooves for the reception of balls or rollers, which are circulated and returned externally of the block or nut.

As shown, a shaft or rod *a* is formed with an externnal helical semi-circular groove *b* and a nut or sleeve *c*, which is adapted to be slipped on the rod, is formed with a similar internal helical groove *d*. Within these coöperating opposed grooves *b* and *d* is disposed a number of anti-friction rollers or balls *e* to form an anti-friction helical screw thread so



ANTI-FRICTION NUT AND SCREW GEARING

that when, for instance, the shaft *a* is rotated in one direction or the other without longitudinal movement, the block or the like *c* is caused freely to move longitudinally thereon without friction. Adjacent to each end of the block c and at opposite sides thereof is drilled a hole *f*, which extends into the groove *d*. Within each of the pair of holes *f* is inserted or screwed a short tube or pipe *g* of sufficient diameter or size to allow the rollers or balls *e* to pass freely therethrough. These two short tubes *g* of the ball race are connected together by another tube *h*, which is wound spirally around and externally of the block or nut c. This spiral tube *h* is connected to the shorter tubes by unions or other suitable detachable means *i*. Midway between the ends of the spiral tube *h* is provided a lubricator *j*, having a wick *k* which is adapted to wipe the rollers or balls *e* during their movement through the spiral circulating tube *h*. This tube *h* is also provided at the upper side with a number of openings *l* for the admission of air to cool the roller or balls *e* during their circulation through the tube *h*.

In operation, the rollers or balls *e*, which are arranged in close contact in the coöperating grooves *b* and *d* between the stops or pipes *f* and in the spiral communicating pipe *h*, will be carried along the block *c* as the shaft or rod *a* is rotated, and will pass through the pipe *h* and be efficiently cooled and lubricated.

*From *The Practical Engineer* (London).

Unnecessary Fatigue*

America's Multi-Billion Enemy

By Frank B. Gilbreth and Lillian M. Gilbreth, Ph.D.

UNNECESSARY Fatigue is one of the world's greatest of wastes. We believe that a conservative estimate of the loss to our nation in productivity alone is *more than* twenty cents per worker for each and every working day. We have arrived at this estimate after many years of intensive study of this subject, in connection with our work as consulting production engineers in this country and in Europe.

There are *more than* three hundred working days in each year, and the United States census shows *more than* 35,000,000 workers whose outputs are affected by unnecessary fatigue. An instant's figuring shows that unnecessary fatigue, therefore, causes a loss in production that is colossal. This loss is much larger than the *total* fire loss, and the *preventable* fire loss is shocking. This tremendous loss is not for one year alone. It runs year after year. It is continuous.[1]

This astounding loss in production is by no means the total loss which is chargeable to unnecessary fatigue. There is also the loss in materials that are spoiled and in overhead charges caused by the unnecessarily fatigued worker. Again, there is the loss due to absences caused by accident and sickness which are often the indirect result of unnecessary fatigue. Statistics show that the over-tired workers are the ones most often injured and most often absent.

There is also the loss due to the lack of coöperation that comes as a result of the discontent due to over-fatigue, and the resentment due to a belief that the management has not done all it could to provide for the workers' relief from unnecessary fatigue.

These losses are real and tremendous, though to some they may seem intangible.

To those who have not considered the astounding costs to our nation due to unnecessary fatigue, or who do not believe that their own organization is paying heavily for not eliminating such fatigue, we recommend the making of a regular Fatigue Survey of their own conditions. We have found that such a survey will pay in an organization, large or small. It will pay when there are 10,000 employees, and it will also pay in the smallest of organizations, even in one's household. We have found it to pay large dividends in the one, and to help solve the help problem in the other.

Another feature that should be brought out in connection with the problem of eliminating unnecessary fatigue is that all countries are now beset with labor troubles. The cost of living and the amount of wages are traveling upward in an endless spiral, and raises of pay, although large beyond precedent, are not satisfying to the worker because their purchasing power is not simultaneously raised. Too many of our population have not the slightest conception that there is such a thing as an actual science of economics, and many of those who have, have no true conception of its principles. This statement does not refer exclusively to those of little schooling. There are many so-called "highly educated" people who are still clinging strenuously to false conceptions and theories abandoned long ago by practical economists. The day when the majority of the voters will be prepared by education to vote correctly on the great economic questions is in the far distant future. Nevertheless there are certain fundamental principles that could be taught in all schools, even in the primary schools.

For example, it should be realized that *a person's true purchasing power is his producing power.* It should be realized that the greater the production the greater the prosperity. It should be realized that any kind of waste cuts down the producing power, and therefore the earning power.

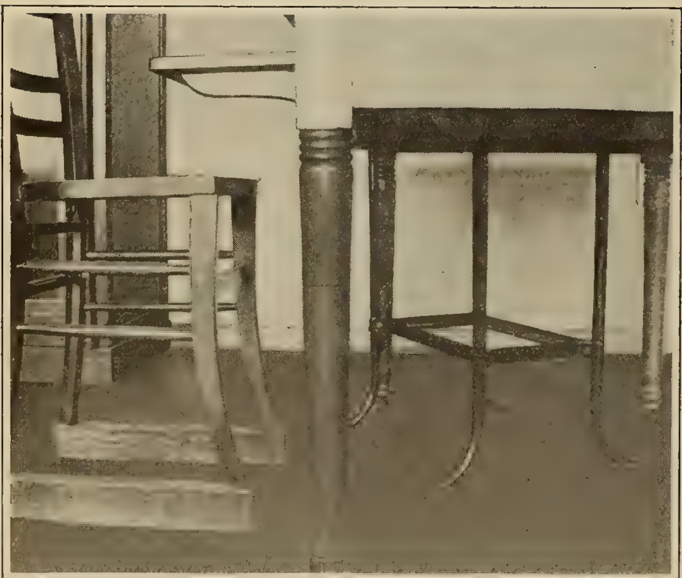
These are most elementary and fundamental principles. It would seem that they are obvious, but on the contrary they are to a large portion of our population by no means obvious. There are hundreds of thousands of people today advocating the reduction of individual outputs as the only cure for all industrial ills.

Now of all wastes and of all hindrances to production, unnecessary fatigue is the most senseless. It does no one any good. Its elimination is a problem in which everyone can share, and all can share also in the benefits derived from this elimination. It is a subject of prime importance because the interests of the employers, the workers, and the public are identical, and therefore coöperation on fatigue elimination will foster better industrial relations.

Let us not postpone the beginning of this campaign for

*Delivered before the Society of Industrial Engineers October 29, 1919.

[1]See "Industrial Fatigue in Its Relation to Maximum Output" by Prof. Henry J. Spooner, C.E F.G.S., published by George Routledge and Sons, Ltd., 66 Carter Lane E. C., London.

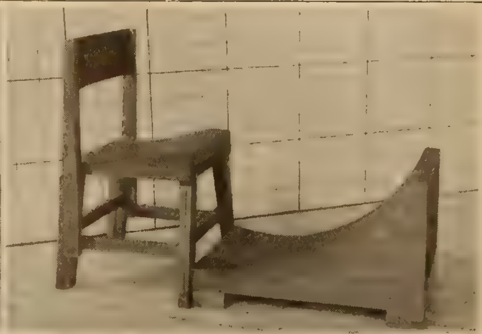


SIMPLE METHOD OF RAISING A CHAIR TO REQUISITE HEIGHT

LATERALLY MOVABLE CHAIR SWUNG CLEAR OF THE MACHINE

IMPROVEMENT ON THE "STANDING DESK" STOOL

ODD ASSORTMENT OF CHAIRS COLLECTED IN A LARGE AND PROGRESSIVE FACTORY



CHAIR WITH ADJUSTABLE BACK AND UNIVERSAL FOOT REST

the elimination of unnecesary fatigue until the division of the profits resulting from it have been determined and agreed upon. The savage Indians knew better than to postpone the accumulation of the spoils until after the arrangement of division was determined. Let the accumulation of the spoils begin at once.

Now how can this campaign be started, and when can it be made? We urge that the first Monday in December each year be recognized as the day on which all organizations take up the subject at meetings of foremen and others, and that the work of other organizations be exchanged and studied. Most satisfactory work has already been done along this line by Professor George Blessing of Swarthmore College.

We have found that the first and logical place to start is with a fatigue survey. The more systematically this is undertaken and the more carefully it is made, the better, but the roughest and most casual survey will instantly reveal oportunities that will more than repay the cost and satisfy any religious yearnings one may have, as an executive or an employer, to comply more nearly with the Golden Rule.

As a matter of fact, the Golden Rule as a method of attack in fatigue study, as well as a law of management has never been excelled. The lack of interest in the past in the fatigue of the workers would justify the old saying, "Man's inhumanity to man makes countless thousands mourn," and inspire a new saying, "Executives' lack of knowledge of the least fatiguing way to make large quantities of production makes countless stockholders kick." This may be the viewpoint necessary to arouse the indifferent manager and add an interested to the disinterested motive.

ALTERNATE SITTING AND STANDING REDUCES FATIGUE

In the fatigue survey perhaps the most important data are those which have to do with lighting, including glare and reflection, and with alternate sitting and standing. There is no excuse today for insufficient lighting or for poorly distributed lighting. Information regarding the good work done by Professors Scott and Clewell and others on efficient lighting is now available, and the shadows and glare from improperly arranged artificial lighting are no longer necessary.

The factory with the machines painted black, the dark dadoes, the "neutral tinted" walls, the piping systems painted distinguishing colors all over instead of at their fittings only, would be ridiculous if they were not so pathetic. All surfaces of all factory workrooms should be painted white. There should be a national law that all enclosed stairways should be painted completely white on the entire ceiling and down to the floor. The whiter the stirway, the more light and the easier for the tired worker to see his way and avoid accidents. More people are killed yearly in the United States by falling down stairs than are killed on the railroads, and the majority of these accidents are avoidable with slight cost and effort. All closets and all lavatories should be painted white.

Walls that are painted a dark color from the floor to a height of from four to six feet can be found in the majority of factories at the present time. This is for the purpose of hiding the dirt. It is the old plan of putting on powder instead of washing the face. The dirt is there just the same, but it is argued, "you can't see it, and it looks nicer." To keep a thing clean, paint it white.

Dirt that shows on the walls and on the machines is seldom of importance compared with the benefits of more light in a factory, and the workers are always more careful when dirt shows. The same thing applies to machines. Our records show that workers keep machines in better condition when they are painted white, and when all dirt is thus made to show. White machines result in less spoilage. The whole tone of workmanship is better when machines are painted white, even when they get daubed with oil and grease.

The present lack of knowledge regarding proper painting often leads to amusing results. We had one client who had painted all interior surfaces of his entire plant the color of pea soup because an artist friend said that that color was "most restful," and in his desire to serve his employees he made the order to paint most emphatic, and the darkest rooms in the cellar were as a result also painted pea green. It is needless to say that they are now being gradually changed to white.

We have carried on some research and studies in our laboratories on finger key-stroke machines, in speed contest work, and in methods of least fatigue, with most interesting results. They illustrate another reason for painting all walls, and surfaces and machines white wherever possible. The depth of focus of the eye is almost exactly proportional inversely to the diameter of the pupil of the eye, and the diameter of the pupil of the eye varies inversely with the lighting. Now the greater the depth of the focus, the less the muscles must adjust the convexity of the lens of the eye. The possibilities of the elimination of the eye fatigue, which means general fatigue is rarely realized, and the simple devices that are now available for measuring actual lighting results are unknown to most executives and workers.

Chairs share with lighting the most important place in the problem of eliminating unnecessary fatigue. Any kind of a chair, steel, box, or rail to sit on is better than nothing. If one must decide between a poor seat and no seat, the poor seat is usually much less fatiguing. Many kinds of work that do not seem to lend themselves to being performed while sitting can be efficiently performed sitting simply by having a chair specially made or altered to suit the individual case. Many kinds of work that appaently cannot be performed while sitting have occasional periods of unavoidable delay during which a worker could utilize that time for resting, if he were provided with a chair available at all times for such periods. Sitting down at least a minute or two each half hour while working makes a big difference in the total fatigue of the day's work as compared with not sitting at all.

Expert salesmen all agree that the seated salesgirl is psychologically handicapped to make the sales and that to sell the average female customer she should be in the attitude and posture of the standing server delighted to serve regardlss of self-comfort. A slogan "Buy of the seated salesgirl" would help this condition.

At almost no cost, factory workers can have their workplaces and chairs designed or altered for their individual measurements, and in the majority of cases should have the table or bench made for working at standing height and a chair arranged to maitnain their elbows the same height above the floor while either sitting or standing. This is not intended to convey the idea of sanction or approval of the too common bookkeeper's chair, with its inhuman round top and its opportunity for the bookkeeper to imitate a woodbine around and through its legs and rungs. That chair was made to satisfy the requirements of a manager of sales of some great furtniture concern who did not care what was done with it after the typical purchaser was convinced that the original price was not high compared with its durability. Most such chairs are too durable. The average chairs of offices and factories are like the traditional definition of a coffin—"The man who made it didn't want it, the man who bought it didn't use it, and the man who used it didn't have much to say about it."

The workers generally have not until recently entered into the fatigue eliminating campaign as heartily as we had hoped and expected. At first we were puzzled, but soon realized that some of the young workers had not so much need of the anti-fatigue devices, and that the strenuousness of youth, of course, set the fashion. The older employees naturally did not care to emphasize their excess fatigue. But when the graphical record shows the difference in production, it puts the matter on a sound footing of economics, as well as comfort and satisfaction, and now we are getting the coöperation and intelligent help from the workers.

Proper eyeglasses will eliminate much unnecessary eye fatigue. Probably no factory can afford to have its workers without the services of a skilled optometrist. The number of workers who need eye glasses or who have improper glasses is much greater than is usually realized. We know of cases in which vigorous workers around forty-five to fifty years old have been tired out, apparently, at quitting time daily and whose earnings dropped off without apparent reason, in some cases as much as 20 per cent, who later exceeded their best records of production after being properly fitted with glasses.

One of the most ridiculous features of our fatigue elimination campaign is the female of the species who becomes thereby convinced of the general principles of the plan, and who becomes most enthusiastic to help in the campaign for the elimination of all unnecessary fatigue, and then comes to work wearing the most pointed toes and the highest of high heeled shoes procurable. This person ranges from the college post-graduate private secretary type to the tuberculous under-paid, under-nourished factory girl from the poverty stricken family.

High heels and pointed toes have their place, a most definite place, and they will probably endure, and their end is not in sight, but that place is *not* in the basket ball court, hand ball court, on the gold links, or the baseball field, *or on the work.* Here is a place in the Fatigue Eliminating Campaign where women at home can help by setting the proper example. High heels and pointed toes worn during the work hours should be made the badge of ignorance or of poverty, or of both. They cause fatigue. They reduce outputs. They decrease national production, when they are worn during working hours. Perhaps they also cause some physical discomfort, but apparently not enough discomfort to offset the satisfaction they give from the consciousness of wearing shoes during working hours that other people wear evenings only. Work should be treated as the greatest of all sports, and working shoes should be selected accordingly.

Life is too short to tell this to women in a plant! It must be made unfashionable by those who set the fashion, and this is no job for production engineers! Women are not, however, the only ones who wear shoes unsuited to their various hours. The photographic records of soldiers' feet permanently deformed by wearing improper shoes prior to enlistment, collected by Colonel W. O. Owen and other officers of the Surgeon General's department are astounding. Mr. Elmer Jared Bliss has done more than any other civilian for correctly fitting shoes to soldiers. It is a fact that over 80 per cent of the soldiers in our army were misfitted before his invention and system were adopted. (See army records.) The one best way to measure and fit shoes has since been micro-motion studied and standardized.

There are some things that we can all do to help. All workers must be taught to arrange their daily work so that it will have less unnecessary fatigue. All workers should be induced to undertake Fatigue study. They should be shown that Fatigue Study is a first step in Motion Study, and usually the most important factor in Motion Study. By studying the phenomena of fatigue, one acquires the habit of thinking in terms of the elements of motions, and as a result increases one's earning power much higher, for the worker who can teach other workers is invariably better paid than one who cannot. Fatigue study will raise one's earning power. It will decrease one's fatigue. It will increase the length of one's productive working life. It will enable one to serve his fellow men. And the possible savings to the nation will be the product of 35,000,000 people working 300 days each year or 10,500,000,000 man-days, times the average amount that the extra productive time and productivity is worth per day. The sum thus arrived at is but the annual payment on Unnecessary Fatigue. The total sum is astounding, especially when it is realized that these great savings are possible with comparatively little effort.

Our country must have greater production in the immediate future. The employers want more profits. Labor wants higher wages. The public must have greater individual purchasing power. This combination can be helped only by eliminating waste. The elimination of unnecessary fatigue offers the greatest opportunity, and the members of this society, under the leadership of its eminent president, will respond to the needs of the people of this nation now, as they did in the world war.

CORN AS FUEL FOR STEAM BOILERS.

WHEN the war cut off Welsh coal from Argentina and a large stock of corn accumulated owing to shortage of railroad transportation the experiment was tried of using corn as a fuel. It was found to have the same calorific value as hard wood or about 2.5 of corn to 1 of best Welsh steam coal. It is usually burned on the cob but if ground to the size of medium sand and blown into the furnace it gives a result in which there is a 2 to 1 comparison with coal.—From *Railway Gazette* (British).

Practical Applications of Selenium—II*

Its Utilization in Biological Chemistry and in the Glass and Rubber Industries

By Louis Ancell

(Continued from Our January Issue)

THE most important applications of selenium lie within the domain of electrical technology and all proceed from the discovery in 1873 by May, a preparer for Willoughby Smith, of the photo-electric property of this substance. This discovery was announced for the first time by Smith in a communication made to Latimer Clark, the President of the English Society of Telegraph Engineers, Feb. 12, 1873. The statement was made that the conductivity of a bar of crystallized selenium augments or diminishes in proportion to the degree of illumination it receives. Werner Siemens was one of the first scientists to utilize this property for constructing selenium cells in 1875. In 1878, Graham Bell, assisted by Summer Tainter, constructed a selenium photophonic receiver which enabled him to hold communications by wireless telephony for a distance of several hundred meters.

The selenium cells prepared by Bell[1] were flat and

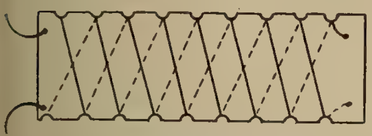


FIG. 1. EXTRA-SENSITIVE WOUND SELENIUM CELL

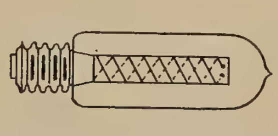


FIG. 2. THE SENSITIVE CELL IN A VACUUM TUBE

consisted of two circular metal plates pierced by holes and separated from each other by a disk of mica. In the holes of one of the plates brass pins were fastened, which penetrated the holes of the other plate, but without touching them. The annular space between the holes and the pins was filled with melted selenium and the whole was then heated over a gas jet, by which means the selenium was transformed into the slatey gray crystalline modification which is sensitive to light.

Bell and Tainter also constructed cylindrical receivers consisting of a pile of disks composed alternately of brass and mica. The mica disks had a smaller diameter than those of brass, so that the annular groove thus left between the two brass disks could be filled with molten selenium. All the metal disks of even rows were connected with one terminal of the apparatus and all the metal disks of odd rows with the other terminal; the molten selenium constituted a semi-conducting bridge between the two poles. In the Bell receivers of the flat type the ratio of the sensitive surface to the total surface is equal to 0.11, while in the cylindrical receivers this ratio is considerably greater, being equal to 0.6.

INDUSTRIAL CELLS.

We ourselves have improved this last device in our industrial cells consisting of piles of metal plates separated by very thin insulating sheets. All the plates are bolted together by carefully insulated bolts, the even plates connected with one terminal and the odd plates with the other by means of conductors brazed upon the plates. One of the faces of the pile is very carefully erected and adjusted, the insulators being flush with the edges of the plates so as to present a surface which is exactly plane without having irregularities scattered over it. Upon this thoroughly uniform surface we pour an infinitely thin layer of selenium and transform it by the conditions described above, to the aforesaid violet ray crystalline modification. These pile cells are quite strong, but their sensitiveness is less and their inertia more marked than in our extra-sensitive wound cells.

The latter, like all cells of this kind are constructed as shown in Fig. 1. Upon an insulating support of suitable nature two naked metal wires are wound; copper wires, for example, well insulated and spaced at a very slight interval apart but always parallel. Two of the extremities are free while the other two constitute the poles of the apparatus. If the support is flat one of the surfaces thus coiled is covered with melted selenium which is then brought to the violet-ray crystalline state by a special treatment under a moderate pressure. If the support is cylindrical the entire surface of the cylinder must be seleniated. In our cells the distance between the two wires is 0.04 mm. and is obtained mechanically by the aid of a special coil winder. The diameter of the wire is comparatively small and usually varies between one and five-tenths of a millimeter. We had observed that this distance corresponds to a normal tension of 4 volts or one volt per one 1/100 of a millimeter of the distance between the electrodes, a distance which it is convenient not to exceed, so as to avoid stresses which might cause deterioration of the cell.

The insulating support must answer to the following conditions: It must be strong, non-fusible at a red heat, non-attackable by the melted selenium and the heated metal wire, non-sensitive to variations of temperature and to humidity, and must act as an insulator when hot as well as when cold; finally it must be capable of being fashioned mechanically so as to be brought to the desired form and dimension.

After winding an attempt is made to insulate the cell and if the result is favorable we proceed to sensitize it and then subject it to different tests, including the resistance to the light of a 16-candle power lamp, placed at a distance of 10 centimeters from the cell and in the dark; the measurement of the intensity of the current which traverses the cell under the same conditions when a four-volt accumulator is placed in the circuit; the measurement of the sensitiveness at various distances (Fig. 3) and of the sensitiveness or non-sensitiveness to radiations of various color; and lastly the measurement of the inertia.

The limits of this article do not permit us to give the details of all these tests; we will, therefore, describe only two, which may possess a certain degree of importance from the

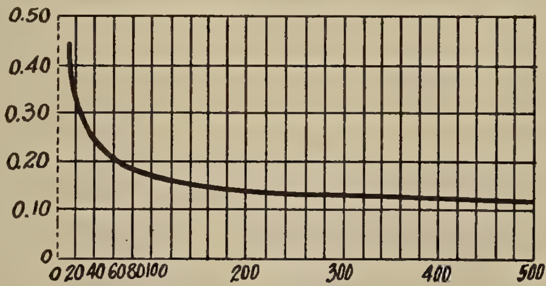


FIG. 3. SENSITIVENESS OF SELENIUM AT VARIOUS DISTANCES FROM A 16-CANDLE POWER LAMP

point of view of applications in industrial chemistry, *i. e.* the measurement of the sensitiveness at different distances and the measurement of the inertia. It should be stated to begin with that these measurements are capable of being made no matter in what mode the cell is constructed.

These measurements may be made, in fact, with cylinders having a seleniated surface; these cylinders (Fig. 2) are

*Translated for the Scientific American Monthly from *Chemie et Industrie* (Paris).

[1]Du Moncel, le Microphone, le Radiophone et la Phonographe, p. 101, Paris, 1882.

generally enclosed in a glass vacuum tube provided with a screw socket like that of an incandescent lamp. Our cells are usually made in the flat form and mounted in a wooden box with or without a cover; the dimensions of the said box vary with the sensitive surface proper, upon which a transparent protecting varnish is spread to prevent air or humidity from producing deterioration of the very thin layer of selenium, whose thickness is, in fact, only one or two 1/100 of a millimeter.

The Measurement of Sensitiveness.—The sensitiveness of a cell illuminated by a source of light having a constant intensity (a candle for example) at increasing distances can be conveniently measured in the following manner: The cell is placed vertically upon a thick support, the height of the flame corresponding to the center of the sensitive surface. A milli-ampere-meter and an accumulator are placed in a circuit connected with the cell. Upon a line perpendicular to the surface of the cell there is then placed a ribbon divided into centimeters; a candle is moved along this ribbon and the distance of the candle from the cell, together with the indication given by the milli-ampere-meter are carefully noted. The curve of sensitiveness is constructed, with the degrees of intensity in milli-amperes in ordinates and the distances in abscissae. The curve obtained shows that the sensitiveness decreases very rapidly at first and afterwards maintains an approximately constant value as the distance increases. This fact is of interest with respect to various applications, particularly in the chemical industry for the control of the draft of factory chimneys (or the stacks of steamboats) and for controlling the rate of progress in a sulphuric acid plant where the catalytic process is employed.

The Measurement of Inertia.—The measurement of the inertia of the cell is of importance for certain industrial or scientific applications, since it is often necessary that the cell should react without delay according to the variation in the illumination which it receives. It is well known that this is not always the case with selenium and an attempt is made either to compensate for this inertia by devices which are sometimes very complex, or preferably to diminish it. It is the latter solution which we have adopted and we have succeeded in obtaining cells whose inertia is negligible from the industrial point of view for the illumination received from luminous sources of a low degree of intensity (from 10 to 100 candle power); this inertia is in general 0.02 per second. The determination of the inertia can be made in the form of curves by the aid of measurements of resistance or, better still, graphically by the following process, invented by us.

For this purpose, the cell under test, is placed at a distance of 10 centimeters from a 16-candle-power incandescent lamp and controls through a 4-volt accumulator one of three styluses of a recording apparatus. These styluses trace records on a drum coated with lamp black. Suppose the right hand stylus is controlled by the cell, then the middle one is vibrated by an electric tuning fork to record hundredths of a second; while the left hand stylus is inserted in the circuit of the lamp which illuminates the cell. This circuit is periodically opened and closed by an electrically operated pendulum. The lamp is momentarily illuminated when the pendulum closes the contact, and is extinguished immediately afterwards. The duration of the illumination, *i. e.* the duration of the contact of the pendulum is 0.15 sec. The cell is influenced by the lamp during this short space of time. The three styluses trace the curves (Fig. 4) which indicate, respectively, at the left, the duration of the illumination between the points A and B in the middle, the hundredth parts of a second, and at the right, the reaction of the cell. Because of the inertia of the various mechanical parts which are in motion, the cell does not react immediately; moreover, this mechanical inertia is constant. The difference between the lengths AB and A_2 B_1 expressed in hundredths of a second, gives the inertia of the cell under test. In the case shown in the figures, AB = 0.15 sec. and A_2 B_1 = 0/17 sec. Hence the inertia of this cell is 0.02 sec., an amount which is practically negligible from the industrial point of view.

Let us add finally a detail which is of some importance: These extra sensitive cells may be made to last a very long time by taking certain precautions, including the avoidance of shocks, of humidity, and of sudden differences of temperature; thus a cell constructed by us in March, 1912, for the photometry of the eclipse, is at the present moment (March, 1919), quite as good as at the beginning. The measurement of the inertia of selenium cells, can also be made as we have

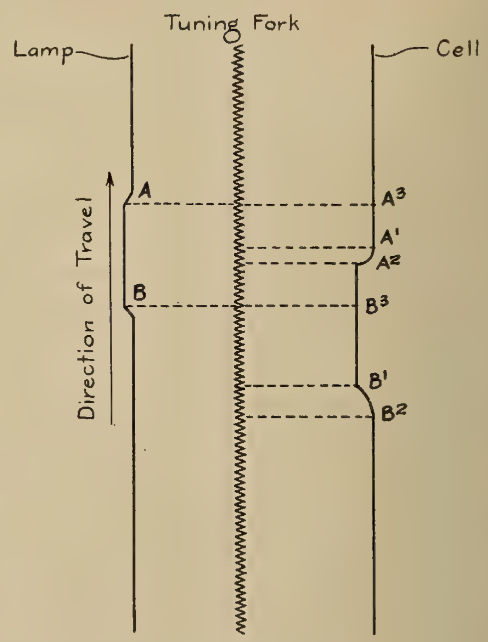


FIG. 4. MEASUREMENT OF THE INERTIA OF A SELENIUM CELL

already proposed[2] by two other distinct processes, somewhat less convenient in character:

1. The graphic process by means of points made by hand.
2. The photographic process, which is entirely automatic, either by employing the device of the oscillograph for the rapid variations, or by the process described for the photometry of the eclipse.

The graphic process consists in measuring under conditions that remain identical the resistance of a cell connected with a 4-volt accumulator and with a sensitive ohm-meter, first in the dark and then in the light of a metal filament incandescent lamp of 110 volts and 16-candle-power placed at a distance of 10 centimeters above the sensitive surface of the cell. Upon a sheet of paper ruled into square millimeters there are laid off in ordinates the resistances expressed in thousands of ohms, and in abscissae the times expressed in minutes.

The resistance of the cell in the dark (after a stay of fifteen minutes at least) is noted and the cell is then illuminated for 60 seconds by opening a shutter placed between the lamp and the cell. We then note rapidly the new value of the resistance and repeat this from minute to minute, the cell being placed again in the dark until its return to the initial value which it possessed in the dark (a period of about 20 minutes). The points thus obtained are then united by a continuous line which gives a curve which descends very rapidly between the first point and the second point and afterwards slowly ascends for the following point. This curve represents the inertia of the cell with respect to a given degree of illumination.

To cipher this inertia we construct the theoretical curve of a supposed cell without inertia, and we integrate, for

[2]Louis Ancel. Avenir de la T.S.F. (Future of Wireless Telegraphy), No. 19, p. 261.

example, by the aid of an Amsler planimeter, the surface comprised between the theoretic curve, the axes of the coördinate and the last ordinate with respect to the last point obained. We obtain a value B. In the same way we make a new integration of the surface comprised between the real curve obtained by points the axes of coördinates and the last ordinate. We obtain a value A, which is smaller than B. Inertia is smaller than 1 and represents the inertia of the cell. The closer the approach of this ratio to unity the better the cell and the feebler its inertia. If we have no planimeter we operate by weighing the paper. The surface B is first cut out and the scrap of paper is weighed to within approximately a demi-milligram; then the same thing is done for the surface A; the ratio of the two rates thus obtained represent the inertia of the cell. It is necessary to repeat the same operations upon a cell in identical conditions at various times in order to obtain an idea of the variations of the inertia and an indication of the vitality of the cell; in point of fact as soon as $\frac{A}{B}$ perceptibly diminishes the cell gradually deteriorates.

The photographic process may be employed in two different ways according to whether it is desired to measure the inertia of a cell illuminated by a source of light whose intensity progressively decreases and then gradually increases after reaching a minimum point, which point may even have complete obscurity (this is the study of the inertia of the cells employed in the photometry of eclipses by means of the apparatus described above); or again by the measurement of the inertia of a cell illuminated by a source of light which has been rendered vibratory by the aid of a sound, for example, in order to study the behavior of a cell subjected to a series of rapid variations and of a feeble luminous intensity (this is the study of the inertia of the cells employed in the process of wireless telephony by means of luminous waves). In the latter case we make use of an oscillagraph or of an apparatus consisting of a sort of Pollak-Virag photo-telegraph. The oscillograph is too well known to need description here. The Pollak-Virag apparatus consists in sum of a photographic recorder in which the mirrors set in motion by the telephone membranes replace the styluses of the graphic recorder previously described.

(To be continued.)

The Art of the Apothecary

Its Ancient Origin and Modern Development in France

By Jacques Boyer

THE maladies from which mankind suffers doubtless had their origin in the earliest eras of human life, and the idea of applying remedies to them must have entered the minds of our most remote ancestors, causing them to make trial, at hazard, of medicaments of whose healing virtues they were in ignorance. Then, when the experiment chanced to be followed by a cure, the same drugs were prescribed in similar cases. Thus were born in human societies the professions of the physician, the surgeon, and the pharmacist.

In an era nearer our own times there appeared in Egypt the class known as "*rhizotomes*," freemen who made a practice of gathering the plants used in therapeutics either on their account or for some professor of the art of healing. There appeared likewise the "*pharmacopoles*," or makers of vegetable extracts, and the pharmaceutribes, who confined themselves to assembling medicaments for sale. As for the products which were used in medicine from the time of Hippocrates to that of Galen and Avicenne, a considerable number are still employed today—opium| and the poppy, among narcotics, wormseed (absinthe) as a febrifuge, eye-salves, cerates, unguents, pomades, etc. While the "Mithridate" (a preparation supposed to protect from poison and to act as an antidote therefor) and the "Theriaca" (an antidote for poison), which contained viper's flesh among other ingredients, are no longer regarded as universal panaceas, we still make use of the formulas of the Arab Geber for certain mercurial preparations.

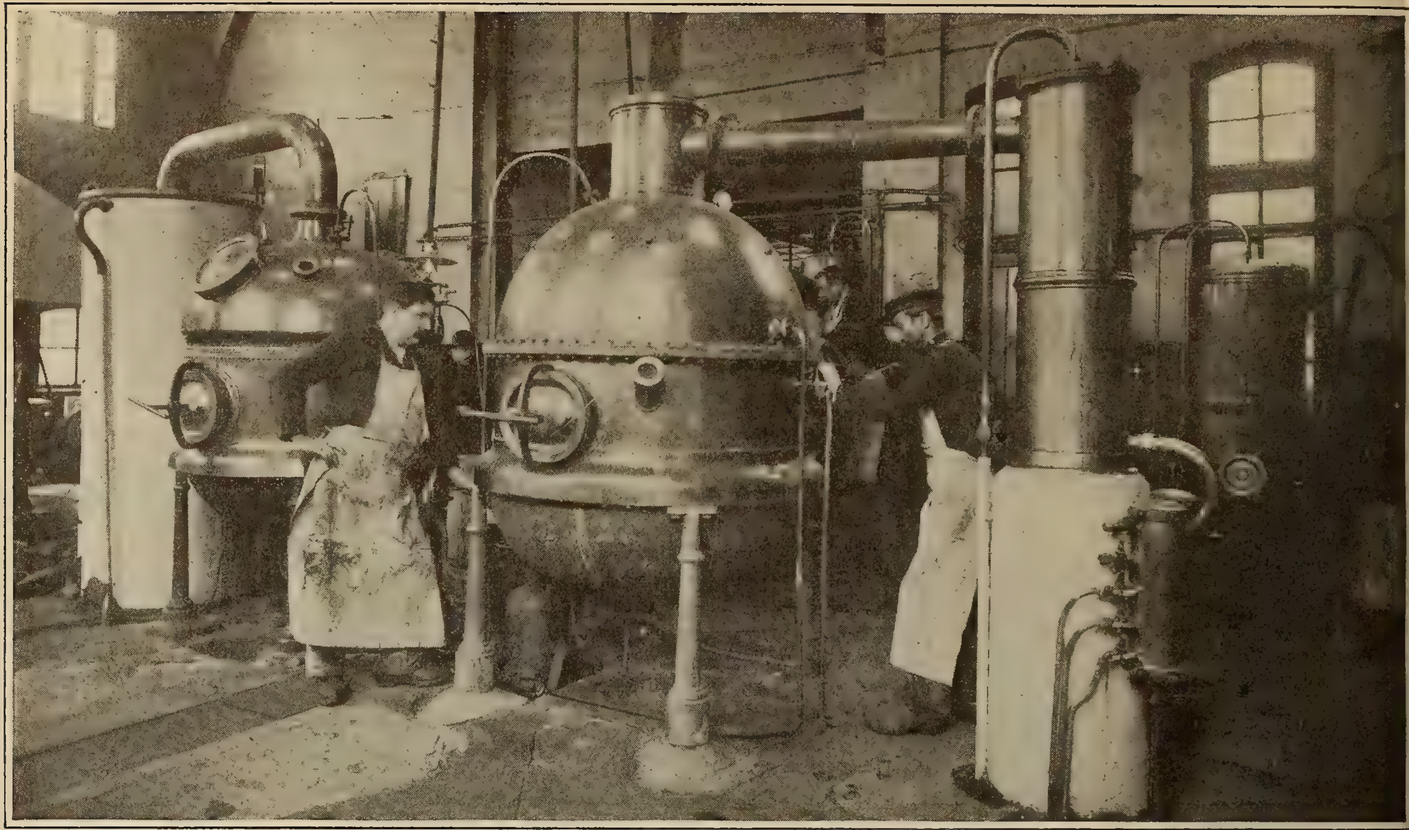
Furthermore the ancient officinal processes of Athens, Rome, and Alexandria much resembled our own. Infusion, decoction, expression, and distillation are currently employed. Modern instruments, to be sure, have been improved, but even in ancient times a well-equipped laboratory included the mortar, the slab of stone upon which to grind and crush materials, and the sieve, among other things. However, pharmacy underwent but slight development among the Greeks and Romans. In Gaul the Druids combined the practice of medicine with religion. They prepared from plants topical applications and various draughts.

Later, when one land had been penetrated by Christianity, the Druidical tradition was carried on by communities of monks. At once priests, physicians, and pharmacists, they had scarcely any rivals in the art of caring for the sick until the foundation of the School of Salerno. But at this period the Jewish physicians driven from Asia Minor by the Arabs, took refuge in France. They brought along, besides the Moslem art of therapeutics, their "Krabadin," a formulary whose composition dates from the ninth century.

However, the first official documents relating to French pharmacy which have come down to us do not go back so far. The existence of this art at Paris is indicated by an ordinance issued by Philipe le Bel (1311), who enjoined upon "grocer apothecaries" the possession of weights and measures. In 1336 Philippe VI le Valois issued an order to the deans and masters of the "very salubrious Faculty of Medicine" to take note of the character of "opiates and laxatives in order to make sure that they are fresh and of good quality." The same edict was issued for Montpellier in 1340. At Bordeaux an authentic record bearing the date of 1355 proves that in this city as well as in the other provinces of France the apothecary was also a grocer. In the following centuries we find that the profession was regulated, and the Swiss physician Paracelsus (1498-1541) enriched the therapeutic arsenal with medicaments having antimony, arsenic, iron, potassium, zinc, etc., as their basic element. The ordinance of Charles VIII., not recorded until May 5, 1520, constitutes a veritable code for the apothecaries of Paris. From this we learn the principal conditions required to be fulfilled by candidates for this profession: First an apprenticeship of four entire years, after which they had to undergo an examination, and finally the composition of a "chel d'oeuvre."

In 1598 Jérôme Périer, Consul of the State, was charged with the editing of the statutes of the Corporation of Pharmacists of Montpellier. The municipality of Dyon had even antedated the capital in this latter point, and in consideration of "the public welfare, profit and utility" they confined the practice of pharmacy from the year 1490 to such persons as had undergone a successful examination before a jury composed of two aldermen, two physicians, and two professionals. About this time there were published the first treatises of pharmacy written in French, among others the "Enrichid or Manipul des Micopoles," by Michel Dusseau (Lyons, 1561) and the "Pharmaceutical Works" of Jean de Renow, both of which had a great vogue.

But while the intellectual level of the pharmacists rose to some degree their fights, now with the grocers, and now with the doctors, kept them from having an easy life of it. The battle was particularly lively at Lyons. However, it termi-



HUGE STILLS USED IN EXTRACTING QUININE

nated in their favor, since in 1571 Charles IX., acceding to the demands of the Lyons pharmacists, granted them two sworn masters, and then a code of 62 articles which underwent a number of revisions and was not definitely promulgated until much later. In 1638 Louis XIII. regulated the mode of reception of the future apothecaries.

To begin with there was a preliminary examination lasting three hours in the presence of six nurses, the two doctors delegated by the Faculty of Medicine, and six sworn masters. Next came the second test, the "act of herbs," and finally the manufacture of a "chef d'oeuvre" consisting of five compositions accompanied by interrogations. The young disciple was then permitted to take his oath and to "deliver his mark impressed upon lead to the the masters of the confraternity." However, since this ordinance established no requirement of responsibility on the part of the vendor of toxic substances a large number of poisonings occurred in the course of the XVII century. This legislative defect was remedied by the Grand Monarch in 1682. By this edict he interdicted the distribution, by masters of pharmacy and by grocers, of arsenic realgar, corrosive sublimate, and other dangerous drugs, except to persons known by them. Each official laboratory was required furthermore to possess a register initialed by the public magistrate upon which the purchasers were obliged to inscribe their name, rank, and residence, the month and the day, the quantity of poison carried away, and the purposed use thereof.

The corporation counted among its members at this time many eminent savants among whom may be mentioned the German Glauber, who discovered in particular the sulphate of ammonia, kermes, and the sulphate of soda; Seignette, the Rochelle apothecary who first obtained in 1662 the tartrates of potassium and of sodium, the purgative still employed both in the old world and in the new; and Nicholas Lémery (1645-1715) a humble apothecary of the Maubert quarter who instituted at Paris the first course upon chemistry with experiments, and whose work entitled "Universal Pharmacy" (1697) was the *vade-mecum* of several generations of students.

The rivalry between French physicians and pharmacists attained its climax about this time. Guy Patin was one of those who were most infuriated against those whom he termed with disdain the "*fricasseurs* [this word means either a bad cook or a worthless waster in general] of Arabia," and the letters of the irascible practician have brought down to our ears the echos of those heroic-comical battles which doubtless inspired Molierè. However this may be, and in spite of the treaties of peace signed between the parties a sullen hostility reigned for nearly a hundred years more between the "*limonadiers des posterieurs*"—as Vade called them in a vulgar jest—and the Faculty. Fortunately there appeared in 1777 the famous ordinance of Louis XVI., which, separating the apothecaries from physicians, grocers and druggists, gave uniformity to the practice of pharmacy throughout the kingdom and put an end to these secular disputes. It is from this year that the College of Pharmacy, which became the only seat of instruction at Paris, dates. It is proper to add that this was, on the whole, a mere transformation of the school founded by a former practician of the Capital, Nicholas Houël in 1578 in which there existed an embryonic form of instruction given by benevolent apothecaries.

Under the revolution charletanism was able to flourish since the decrees of 1791 had proclaimed the freedom of commerce; but following upon the occurrence of numerous accidents the National Assembly decided to maintain in force the former pharmaceutical regulations; however such abuses continued to occur until the promulgation of the law of Germmial 21, year XI. (April 11, 1803) which created six schools of pharmacy for the whole of France and treated of the mode of reception and of the practice of the profession. The main features of this still exist with modifications which are of interest only to members of the profession. We may mention in particular that since 1899 there has been no pharmacist of the second class in our country; the sole professional diploma is that of the first class.

From the end of the XVIIIth century until our own time, pharmacy has benefited by numerous scientific discoveries, more than one of which issued from the crucibles or retorts of skilled apothecaries. In this modest laboratory at Koeping did not the Swedish Scheele (1742-1786) isolate chlorine, so important in matters of health, and glycerine, whose applica-

tions in medicine are multiple? Baumé made popular areometry, universally employed since his time; Robiquet discovered caffein; Pelletier and Caventon became famous by the preparation of the sulphate of quinine (1828). Finally, nearer our own day, we have as a result of the memorable researches of Pasteur (1822-1895) and his pupils, the introduction of serums into current therapeutics. Thus progress has given a new orientation to the profession of pharmacy. These medicines, often of highly complicated formulas, these biological or other products prepared under the laws of asepsy or antisepsy, these animal serums, can no longer be made in the back room of an apothecary shop. Their manufacture must be monopolized by a few great factories by Pasteur Institutes or by physiological laboratories.

This is an accomplished fact today. The accompanying photographs will enable us to penetrate these little known establishments where remedies which are employed in infinitesimal doses—such as quinine, for example—are obtained in hundreds and thousands of kilos.

How modest seem the utensils of the apothecaries of old compared with these gigantic vats where sulphate of magnesia is crystallized; or with these enormous alembics where quinquina and cocaine are being elaborated; or with these heavy mortars and stout pestles which crush benzoate of soda all day long!

As a matter of fact the raw materials furnished by nature are rarely capable of direct use in the art of healing. They must undergo various manipulations whose object is to facilitate the method of administering them to the patient—in a word, to sugar the pill for the invalid! Let us make a rapid review, therefore, of the principal modern methods by which the various pharmaceutical forms are obtained:

In the herbarium, a more-or-less extensive storehouse, are kept the wood and barks, the freshly gathered plants are either spread out or hung up to dry; when completely desiccated they are placed in carefully labeled packages until such time as they undergo division by means of shaving machines (sandal wood, quassia), by triturators (the granulation of cinchonas), by winnowing-machines and mill-stones (linseed meal); or until they are pulverized in cast iron mortars by mechanically operated pestles; or until they are ground between granite mill-stones or sifted in order to obtain a powder of the degree of fineness exacted by the codex.

Distillation is employed in the preparation of the hydrolates and the alcoholates—*i. e.*, those medicines in which water and alcohol respectively constitute the vehicle of the basic medicinal substance. In the majority of cases vegetable substances are employed either while fresh or after desiccation. They are macerated for a period which varies from 24 hours to several days, then placed in a retort and distilled over a water-bath. Sometimes the distillation takes place in a vacuum, which considerably lowers the boiling point and prevents the decomposition of the essential oils. Let us take as an example the method of obtaining the valuable febrifuge quinine. It is extracted from the bark of the cinchona, which is first broken up, pulverized and sifted by mechanical means, and then mixed with a certain amount of lime; the mixture is then extracted by heavy petroleums in a vacuum retort.

As a usual thing underground pipes deliver the hydrocarbons to the apparatus. Pumps deliver the quantities needed daily into an enormous cistern so as to avoid the accumulation of inflammable substances in the work-shops. Cinchonine and quinine, the alkaloid which the cinchonas contain, are dissolved in the petroleum, from which they are liberated upon cooling. They are separated by converting them into the sulphate which is then allowed to crystallize in huge vats. The sulphate of quinine is deposited, while that of the cinchonine, being more soluble, remains in the mother liquor. Complete purification is secured by successive crystallization, after each of which the product is collected in powerful centrifugators which rapidly eliminate the mother liquor. Finally the purified sulphate of quinine is spread upon wicker-work covered with absorbent paper and placed in an oven. After being thoroughly dried the product is ready to be packed in bottles or boxes.

Dry or soft extracts are obtained by the more or less complete evaporation of a solution of an animal or vegetable product in order to reduce to a comparatively small volume the active medicinal principles it contains. Although the discovery of the alkaloids, acids, glucosides, and other definite compounds contained in plants has diminished the importance of the extracts, basins having a capacity of 230 to 500 liters and retorts holding 1,500 liters are often used for preparing the aqueous extracts of cocoa, of kola, of digitalis, and of opium; the alcoholic extracts of colchicum and of hyosciamus; the etheric extracts of cantharides and of the male fern. As for the extracts termed "robs" they are obtained by the direct

THE "MAGDALIONIER" FOR MAKING RODS WHICH ARE LATER FORMED INTO TABLETS

FILTERING LIQUIDS ON WOODEN TRAYS IN THE KERMES LABORATORY

HUGE CALDRONS IN WHICH PILLS ARE SUGAR COATED

evaporation of the natural juices of plants, such as those of aconite, lettuce, belladonna, and hemlock.

Let us now attempt to obtain an idea of the importance of the production of certain medicines derived from the mineral kingdom by chemical means. Let us enter the kermes workshop in the "Central Pharmacy" of France at Saint-Denis, where we may see 25 sheet iron vats having a capacity each of 1,200 liters, provided with pipes of large diameter and with stopcocks by means of which they can communicate with each other or be shut off at will.

Herein there is boiled for one hour a mixture of sulphide of antimony, carbonate of soda, and water, which is then allowed to pass into the evaporators that have a capacity of 5,000 liters. The liquid is filtered while hot and upon cooling there separates from it a brown, light, velvety powder which is placed upon wooden wicker-work covered with paper to dry; this powder constitutes the kermes which is used in doses of 5 to 20 centigrams as an expectorant. Not far from this room, in the same factory is a furnace wherein from 5 to 6,000 kilos of magnesia are annually calcined—*i. e.*, a quantity sufficient to purge 4 or 5 hundred thousand persons! The washing of the carbonate of magnesia requires 20 vats each having a capacity of 2,000 liters and the desiccation of the cakes of this salt is accomplished upon shelves arranged in a vast oven.

Equally large are the vats heated by steam in which the solutions of sulphate of magnesia are daily evaporated. From these troughs conduct the liquids into the crystallizers, where they are transformed into pretty, white crystals which are removed by workmen with mallets. Eighty thousand kilos per year of this salt are manufactured at Saint-Denis.

Chloroform alone often occupies a separate room whose windows are provided with black curtains. In order to prepare it 10 kilos of the chloride of lime are mixed in a roomy retort, with 3 kilos of slacked lime in 80 liters of water; to this mixture two kilos of alcohol are then added and the whole heated by means of a current of steam, care being taken to have the container only about one-third full. At about 80° C. the mass begins to seeth and almost pure oxygen is liberated. At this moment the fire is extinguished and the distillation begins. As soon as the boiling stops a second quantity of the first mixture is introduced into the retort, and so on until it is full. The heating process is then begun anew and a product is collected which consists of chloroform, water and alcohol; after being condensed in a worm this product flows into a metal container. Since the chloroform is denser than the two other substances it is easily separated; it is then washed with water and with potassium carbonate, afterwards being dried over calcium chloride. Since the final product must be extremely pure in order to avoid accidents in the course of surgical operations it is necessary further to rectify it by shaking it up with sulphuric acid, washing it with a soda solution, and then, after stirring up with pure oil of cloves, redistilling once more, removing the first and the final products.

We must not leave the anesthetics without describing the apparatus which is employed to extract the leaves of cocoa in order to obtain cocaine, which also renders excellent service to modern surgeons and dentists. As soon as the liquid has been extracted and filtered it is precipitated by the acetate of lead; then, after removing the excess of the latter by means of the sulphate of soda the resulting compound is shaken up with ether, which dissolves the cocaine; this is transformed in the chlorohydrate, which is extracted by centrifugation.

The workman then removes the pocket of cloth which contains the valuable crystalline flakes and spreads these upon filter paper laid upon wooden plates which are put in the oven until the product is dry.

Let us now consider the various forms of pharmaceutical substances by means of which medicines having a disagreeable taste or odor can be easily administered. Formerly it was considered sufficient to envelop bitter powders with unleavened bread which had been previously moistened. But about the year 1872 a practician of Paris named Limousin conceived the idea of enclosing them in capsules of the same substance. They are now made by means of a sort of waffle-iron. These molds consist of iron plates containing small cells between which a starch paste is introduced, and they are set on a gas stove.

The same purpose is served by capsules having an envelope of gelatin. The envelopes are made by inserting iron forms shaped like olives in a solution of gelatine and gum. The stems of these "olives" are held in a plate which the operator rotates back and forth so as to secure regularity of the viscous layer which adheres to the forms. She then withdraws the forms from the solution and when the capsules are sufficiently dry she slips them off the forms and places them orifice upwards in sockets formed in a board, to be filled with the desired liquid. When the capsule is full it is closed by

passing a brush dipped in the gelatinous solution several times over its orifice.

Another process which is widely employed for ether, spirits of turpentine and other highly volatile substances was invented by M. Thévenot. The liquid is poured between two plates of solidified gelatine whose edges are welded together

BOTTLING COD LIVER OIL

by enclosing them between the two jaws of an indented metal mold, which is placed in a hand-press. In this manner beads are obtained having the form of a flattened spheroid; these beads are readily separated from each other by hand upon issuing from the machine.

Lozenges are made by the aid of an ingenious apparatus. A paste is first prepared of the pulverized or dissolved medicament incorporated with sugar by means of gum tragacanth. This paste is then malaxated and rolled out. It then passes between two series of cutters which automatically cut it into pastilles. In order to prepare the paste of marsh-mallow or of lichen the medicinal substance is incorporated with melted sugar and then introduced drop by drop into special molds by means of a dropper. The molds are made in the following manner: Rectangular wooden boxes are filled with powdered starch and then placed beneath a press which forms a series of holes in the starch and into these the fluid paste is introduced.

The manufacture of pills is accomplished by means of pestles and of the "magdaleonier." The first step is to mix the active substance by means of mechanical pestles, which consist of enormous vertical beams covered with a heavy mass of metal. These are given a rotary motion by means of suitable gearing. As soon as the product has been pounded to a suitable degree of fineness, in case it has to be pulverized, there is added to the glycerine solution a syrup, an extract, or some other agglutination, in order to give it the proper consistency. If, on the contrary the mass is liquid or too soft an inert powder is incorporated with it. The paste is now ready to be formed into pills. For this purpose it is rolled into "magdaleons" or cylindrical rods which are compressed between the superposed grooves of a machine, called a "magdalonier." The small balls thus obtained are preserved in lycopodium powder in order to prevent them from sticking to each other. Then the balls are rolled out into tablets.

Sugar coated pills are obtained in a manner almost identical to that in which ordinary bon-bons are made, except that the nut is replaced by an agglutinated preparation—iron, mercury, anise, digitaline, atropene and other active principles. The kernels are placed in a caldron called the "Branlante" which is heated and has a rotary motion. Into this gum dissolved in a little water is gradually poured and then a perfumed sugar syrup is slowly added. The kernels are covered with this mixture by rolling against each other, and by the adding of fresh syrup a number of times they gradually become covered with a sugar envelop. They are whitened by adding a little starch to the mixture end are finally placed in the oven to dry.

Let us now leave the confectionery room and descend into the cellars of the great drug factories, where the oils, balms, and unguents are manufactured. Let us first glance at the great cylinders made of galvanized sheet iron, which have a capacity sometimes of 1,200 liters in which cod liver oil is delivered directly through an opening in the floor of the warehouse above, just over each of its containers. After the first period of settling the oil is allowed to float into huge cisterns each capable of holding 6,000 liters; afterwards it is pumped into filters which distribute it into huge vats lined with zinc and ranged along the wall of the ground floor; the spigots of these pass through a partition into another room, where operators are employed in bottling, corking, and labelling the oil or putting it into capsules.

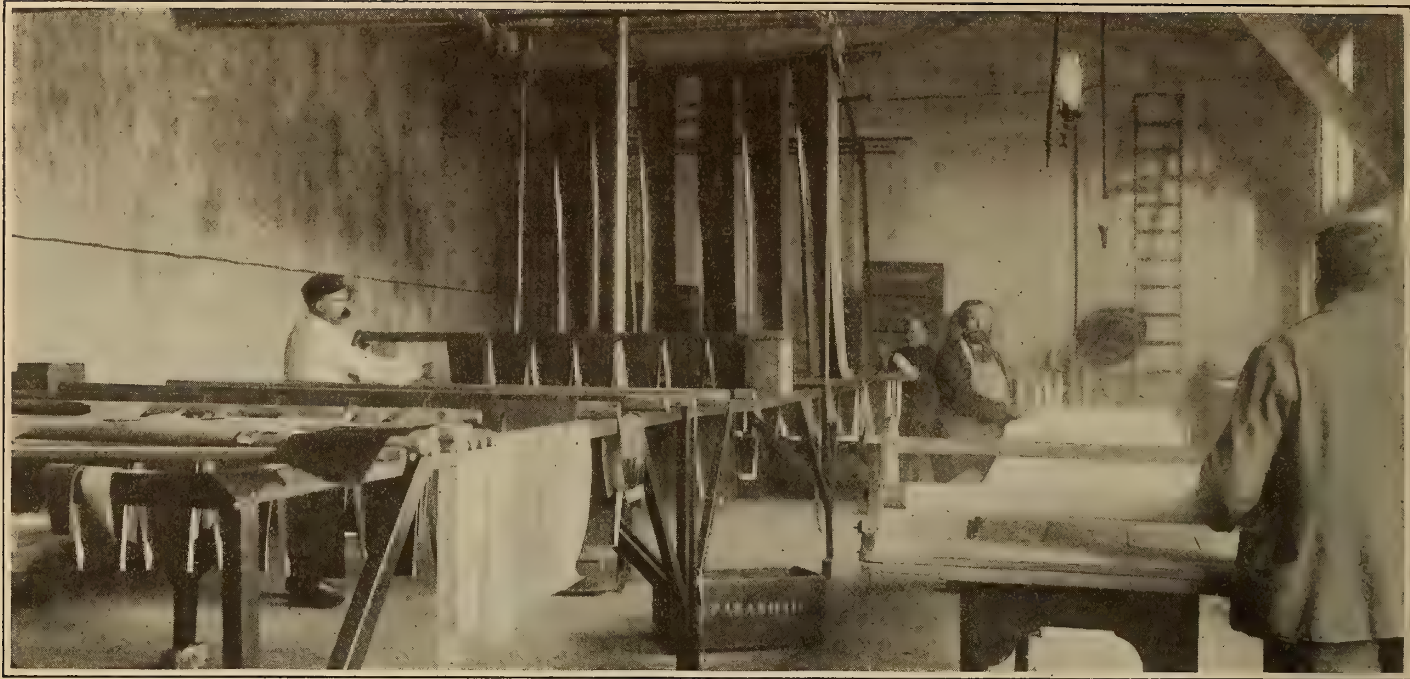
Unguents and pomades are often prepared in cellars adjacent to those containing the oils, either by a simple mixture, by means of solution, or by boiling the fatty substances with the active principle. The container is usually a copper basin provided with a mechanical mixer. This basin can be heated over a water bath or not as the case requires. The fatty substance mostly employed is vaseline, since it has the valuable quality of not becoming rancid.

Sparadrap or adhesive tape is usually made of unbleached cotton because its fuzzy surface retains the plastic material, but silk is likewise used. The cotton is cut into strips 5 m. long and 20 cm. wide, and the melted plastic material is then poured over it. The adhesive bands are dried in the open air and then rolled and placed in boxes.

Since the admirable researches of Pasteur and Koch and of Roux, it is a well-known fact that injection of the blood of an animal immune to a given infection into the veins of other living creatures which are susceptible to the same malady, renders the organism of the latter more resistant. For this reason modern practice gives battle to many morbid infectious conditions, such as cholera, small pox, dyphtheria, variola, or tetanus, by means of anti-microbian serums extracted from

FILLING GELATINE CAPSULES

the blood of animals which have been previously rendered immune. Such products are prepared in special scientific establishments. For example, physicians procure from the Pasteur Institute anti-diphtheric and anti-tetanic serums which are obtained in an annex situated at Garches (Seine et Loire). At this place a hundred horses are kept, in which culture of



MAKING SARADRAPS OR ADHESIVE BANDS AND TAPE

the microbes of diphtheria or of tetanus are injected. As soon as these animals have been rendered immune their blood is collected by means of a trocart induced into the jugular vein and a rubber tube connected with a receptacle which has been previously asepticised. This container is then carried into a cool cellar and after a lapse of, at least, twenty-four hours the serum can be extracted by simply siphoning off the liquid.

Such medical preparations are derived from special laboratories where pigs annually "manufacture" gastric juices, known commercially under the name of dyspeptine or pepsin. Dr. Maurice Hepp was led to found this establishment because he had succeeded in curing many of his patients afflicted with serious stomach troubles by means of the so-called gasterine of Frémont (the gastric juice of the dog). He therefore resolved to study the question further in order to avoid certain inconvenient features involved in the use of gastrene, especially of its too great acidity. After many fruitless experiments he successfully replaced the dog by the pig, which has a stomach of very considerable capacity as well as highly remarkable powers of assimilation and whose gastric juice is very similar to that of man, being only slightly acid. He began by studying the various modes of operation which might enable him to collect the living secretion and finally decided upon the following: He excludes the stomach from the alimentary canal by cutting the oesophagus above the cardia and connecting it with the duodenum. He then produces a gastric fistula through which the secretion can be drawn off.

When a pig is operated upon it is placed upon a surgical table and chloroformed, for, as one can readily understand from the description this operation is very long and serious in character. Thanks to this surgical invention the food taken by the animal does not pass through the stomach which continues, however, to secrete the gastric juice abundantly at the very moment of the food's ingestion.

The subject of the operation recovers after a very short lapse of time and in order to collect its gastric juice it is only necessary to suspend the animal by means of a special harness about forty minutes after its meal and introduce by means of its fistula which has been previously asepticised a tube which delivers into a flask a considerable quantity of the secretion, while the surplus passes into the deodenum through the pylorus, which remains open thus maintaining the proper physiologic function of the patient. That this is true is proved by the fact that upon the farm at Puits d'Angle where the Hepp "dyspeptine" is manufactured, one finds animals which have lived for three years and more in spite of the stomach fistula and which steadily increase in weight. The gastric juice thus collected is turbid and since it contains an enormous microbian flora it is nesessary to filter it under a slight pressure of carbon dioxide. Dr. Hepp makes use of carefully sterilized filters and the extracted juice issues from these perfectly limpid and of a pale amber color. After being bottled for a fortnight a powder is deposited upon the bottom of the flask. A little bit later the product melts under the influence of luminous rays.

Finally if we would speak of all the "factories" which supply modern pharmacies, it would be necessary to describe other enormous establishments also; for example, the one at Bourg-la-Reine, which is similarly devoted to the sterilization of absorbent cotton, bandages, cat-gut and other surgical material—workshops where bandages and other orthopedic materials are continually turned out. But we must bring this brief story to an end since the remedies devised to alleviate our physical sufferings are innumerable, merely remarking that many of them affect our purses more than our ailments.

EXTRACTING PEPSIN FROM A PIG IN A VIENNA LABORATORY

Preventing Rail Fractures Resulting from Minute Fissures*

"Ageing" Metal Restored by Annealing

It has been frequently observed by many investigators that iron rails are often fractured, though containing no defects due to the process of manufacture, because of the formation of very fine fissures upon the rolling surface after the lapse of a certain amount of time. Most authorities who have called attention to this phenomenon have recommended a minute examination of the road bed from time to time, for the purpose of removing rails which have undergone this alteration. Very recently, however, the question has been studied from a new angle by MM. Georges Charpy and Jean Durand. They have endeavored in the first place to determine the method of formation of these minute cracks and secondly to reproduce them artificially, with the object of discovering some means of preventing their production which should be at once less costly and more certain than the mere process of removing the affected rail.

In the course of their researches, an account of which was recently presented to the French Academy of Sciences, they proved to begin with that the phenomenon is very general in occurrence, being by no means confined to rails. This phenomenon is found in a large number of cases whose common characteristic is that the steel has been subjected to an intense degree of "hard hammering" or pounding, which has been limited to a superficial stratum. Under such conditions this stratum appears to be subjected to strains of the same sort as those which are produced by the interplay of movements of expansion between a ceramic paste and its covering, and which give rise to fractures from what are called "tremors" or vibrations. The cracks in steel are produced when the surface of the metal has been sufficiently hammered to cause it to break without undergoing perceptible elongation.

As might be supposed from the foregoing remarks the phenomenon is particularly well marked in the case of very hard metals. In the case of white cast iron, in particular, it only requires a rather rough rolling to cause the appearance upon the rolled surface of a network of fine cracks, very similar to that observed upon rails. The same experiment (the production of cracks by rolling) can be repeated with tool-steels which have been rapidly tempered, as well as with hard chrome-nickel metals (metal for shells).

These fissures, which are often extremely minute, can be accenuated by treatment with acids. It even appears to be true, according to the present authorities, that in certain cases the acid "develops" these fissures which existed in the metal in a latent state, being so slight, however, as to be undiscernible by the most minute microscopic examination of the polished surface; in such a case the cracks will be produced as soon as the resistance of the superficial layer has been sufficiently reduced by means of the thinning action produced by the action of the acid.

Analagous results can be obtained by other methods. We will cite one example only, which is, however, very striking in character. This consists in hammering the surface of a very hard metal by making upon the said surface the imprint of a ball by impact, according to the manner adopted in measuring hardness by the Brinnell method. Under such conditions one sometimes sees very fine fissures upon examining the imprint of the ball under the lens of a microscope; but even when the metal appears to have remained perfectly compact it is only necessary to attack it with acid as described above in order to observe well defined radiating fissures, which are usually arranged in the form of a regular star. The length of these fissures would seem to indicate the extent of the hammering produced by the ball around the imprint itself. This experiment succeeds admirably with rapidly tempered tools or upon the points of bursting-shells.

In the steel of average temper which is used for rails (having a resistance of from 65 kg. to 70 kg.) the total surface hammering is much more difficult to obtain; the work of rolling is powerless therefore to produce this result. In order to reproduce the phenomenon observed on railway tracks we, therefore, conceived the idea of making us of the analogy which exists, as long ago pointed out by Duguet, between the rolling of trains and the work of the rolling mill. The test is all the more readily made since rolls are frequently employed which are made of a semi-hard steel of a temper identical with that of which rails are made. But in a great number of these rolls we have been able to observe, after they have been in service for a certain length of time, cracks which are strictly identical with those produced upon the rails.

We have also observed the same phenomenon upon the trunnions of steel rolls.

It is worth while to mention here another example which at first glance appears to be very different from those described above: this is the phenomenon of the erosion of the bores of cannon which have been made the subject of various studies, including in particular the quite recent researches of Professor Howe and of Mr. Fay. Upon examining the surface of the gun bore at the moment when the erosions first begin to appear, one readily recognizes the presence of fine cracks which are identical with those of the rails and rolling cylinders described above, and which may be attributed to the hammering or rolling action of the projectiles upon the riflings.

This example, as well as that of the mill rolls, leads to the belief that the formation of cracks in semi-hard steel occurs much more readily at a temperature above normal. There is nothing surprising in this, however, for it has long been known that hard hammering is particularly dangerous for steel at those temperatures at which the metal is colored by oxidization (hard hammering at the blue heat). In the case of the railroad rails this condition may occur, indeed, in the slidings caused by sudden applications of the brake, under which influence a considerable elevation of temperature is produced, as we know.

The above observations indicate also that in the case of semi-hard steel the hammering required to occasion the formation of cracks can not be instantaneously produced, but necessitates a series of repeated actions which produce a gradual hardening of the surface. This view is corroborated by statistical relief maps. A very complete map of this sort has been received by me from M. Euverte of the P.L.M. railway system. If upon this map we place the curve representing the number of fractures of rays in function of the duration of the service, we find that it exhibits a sudden change of direction after a lapse of about ten years, after which time the number of fractures, which was previously very small, rapidly increases. We are here concerned, therefore, with a progressive "ageing" of the rails, in which ten years represent a "critical age" so to speak, at any rate in the case cited.

This observation enables us to discover a remedy for this condition. As a matter of fact the hardening produced by the hammering can be constantly suppressed from time to time by a suitable annealing; if this annealing is effected before the cracks have been formed the alteration produced is completely annulled—in other words the effect of the ageing process is suppressed, and we may say, therefore, to carry out the metaphor, that we have affected a "rejuvenation" of the metal which practically restores it to its original condition. This deduction can be readily illustrated by means of the experiment cited above concerning the impression made by a ball upon hard steel. If after having made the impression the metal is

*Translated from the *Comptes Rendus* of the French Academy of Sciences for the *Scientific American Monthly.*

annealed we find that it may be attacked to great depth by an acid without occasioning the slightest appearance of a fissure. This superficial annealing is comparatively easy to apply in the case of rails. Descriptions have recently appeared of ovens mounted upon wheels devised for the purpose of producing superficial tempering of the rolling surface of railways. The same apparatus can be used for annealing even more readily. If this annealing be done before the critical age of ten years is reached there is every prospect that it will be possible to diminish very considerably the number of fractures due to cracks. Without further insisting upon this view to which we hope to return later, we feel it advisable to point out its very general character. Whenever a piece of metal is liable to undergo alterations by means of local hard hammering, which develops gradually in the course of service—and examples of this are very frequent, not only in rails but in chains, bolts and pins, braces, etc.—this effect may be counteracted by annealing at suitable intervals. To continue our figure of speech we may say that the "duration of life" of certain pieces of metal may be considerably prolonged by "thermal cures" applied at suitable intervals. Needless to say we have here a possible means of economizing metal which should not be neglected.

WIND-POWER ELECTRIC PLANT

MR. JANSON, of Sweden, has erected a new windmill near Stockholm for the purpose of generating electricity. The irregularity of the wind is equalized by compelling it to raise a heavy weight to a considerable height and the energy developed as it falls being utilized to drive a dynamo, instead of the usual direct drive.

The mill wheel has four 18-foot sails which make 30 revs. per minute. The total surface exposed to the wind is 244 square feet, and produces 6.22 h.p. when the wind has a velocity of 23 feet per second. The wind-motor and dynamo are mounted on a bracket on the top of a 20-foot steel mast, and turn automatically to the wind. The mast is in turn supported from a timber structure 33 feet high, the lower portion of which, together with a ground surface of 269 sq. feet, are roofed over to a height of 11 ft. 6 in. for housing the switch-board and storage battery. This consists of 65 cells with a capacity of 150 ampere hours when discharging at the rate of 45 amperes. The current is used for lighting a manor house and for agricultural machinery. The 2-ton weight used to drive the dynamo is suspended from a chain and raised by a special gear. The arrangement is very sensitive, and even the slightest wind will raise the weight slowly through an automatic variable speed gear, while a ratchet wheel and pawl prevents any reversal of the moment.—*Gustav Sellergren* in *Tekrusk Tidskrift* (Sweden), abstracted by the *Technical Review*.

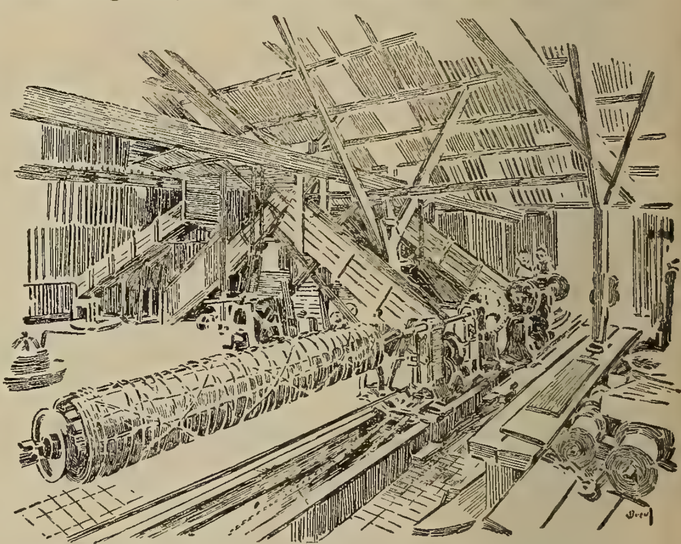
REINFORCED-CONCRETE PIPE MADE BY THE CENTRIFUGAL PROCESS.

CONCRETE pipe which have been tested without serious rupture for an interior water pressure up to 400 lb. per square inch are being made by the centrifugal process for a number of uses in Australia and South Africa. The method of manufacture was developed by W. R. Hume, of Adelaide, South Australia, and the pipe are being made under concessions from him. In brief, the system consists of whirling a pipe mold full of concrete on a horizontal mandrel, trusting to the centriugal action to compact the concrete.

The pipe are being made in 4-, 6- or 8-ft. lengths. The reinforcement is of wire. In South Africa old steel winding ropes from the mines are heated, to anneal and soften the wires and to burn off grease. They are then wound in various ways upon revolving cylinders of the same diameter as the inside of the pipe, a sort of ropewalk being used for unwinding the strands of old rope.

The mold consists of a flexible 1/16-in. steel cylinder cut in half lengthwise and re-joined by hinges and clamps, so that when it is opened the pipe can be removed. This mold is placed horizontally on the rotation friction rollers of the casting machines. When a pipe is to be made, the steel wire reinforcement is placed inside the mold. Flanges, the same depth as the required thickness of the pipe walls, are placed on the end of the mold, and wet concrete of various grades corresponding to the quality of the pipe required is introduced from the ends, which are open except for the flanges mentioned. The pipe is revolved slowly at first, and the concrete is automatically distributed evenly along the whole length of the pipe and around the circumference, and completely incases and embeds the reinforcement.

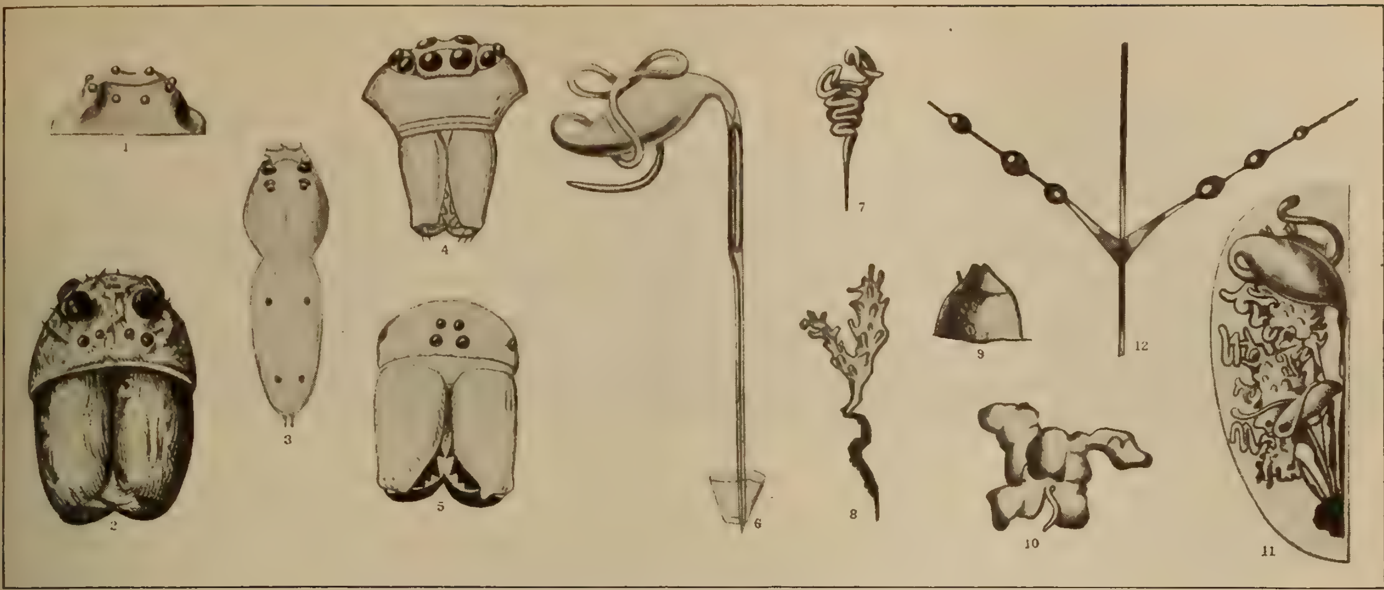
The pipe is then revolved more rapidly, and the excess water, with any impurities, is collected in the center of the pipe and drawn off at the ends. Pipe of 4-in. diameter can be "spun" out at the rate of one per minute. Pipe 6 in. in diameter take 2 min.; 18-in. diameter take 8 min., and 48-in. diameter 20 min. The concrete by this time has set so hard that it is impossible to make an impression on it with the finger. The molds are run into a steam house for 24 hours and then opened, and the pipe are seasoned in water tanks for a month, usually. Pipe can, however, be put to use within a week. The pipe show a remarkable density, and are impervious to great pressures either in sections or as a continuous line. A joint as strong as or stronger than the main itself has been designed. The ends of the pipe are recessed and butted together, forming a diamond-shaped cavity between



Courtesy "Engineering News-Record"
REINFORCED-CONCRETE PIPE ON A MANDREL IN THE SHOP

them. A collar 6 in. wide, of strength similar to that of the pipe, it put on and secured with a backing of cement at both ends. Between the pipe a plastic bituminous cement is inserted, and pressure tends to compress this in the annular cavity of diamond-shaped section. This makes a joint which has been tested to 400-lb. pressure. Experiments show that a pipe designed for 100-lb. pressure shows at 200 lb. faint lines of dampness; at 250 lb. this becomes a dew. At 300 lb. the dew develops into a heavy sweat, and at 350 lb. jets of the finest misty spray appear. If this pressure is reduced the pipe takes up and is as capable as before of carrying 100-lb. pressure.

Until 1916 there was considerable skepticism concerning the suitability of these pipes for high pressure. In that year J. C. Ross, city engineer of Hobart, recommended the installation of 10 miles of 18-in. pipe to pass 13,000,000 gal. of water per day under a head of 250 to 350 ft. This line was successfully laid with a saving of $15,000 over cast iron, and the pipe is now almost universally used in water-supply and irrigation projects in Australia. Cylinders 10 ft. long and 6½ ft. in diameter are being made by this process for use in harbor works at Burnie, Tasmania, and cylinders 15 ft. in diameter have been made for use as buildings and silos.—*E. M. Weston* in *Engineering News-Record*.



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SPIDER FACES AND SILK-SPINNING ORGANS

1. Model showing anterior row of eyes recurved. 2. Licosa carolinensis; eyes in three rows. 3. Eyes in four rows; Lysomanes. 4. Face and cheliceræ of Theridion. 5. Face and cheliceræ of Aranea. 6. An ampullate gland. 7. Cylindrical gland. 8. Aggregate gland. 9. Hind spinneret of Steatoda. 10. Lobed gland. 11. Section of abdomen showing silk glands.

Spiders as Mechanics*

Their Skill as Weavers, Miners, Builders, and Aeronauts

By Professor E. L. Bouvier

Member of the French Institute, Professor at the National Museum of Natural History in Paris

WHO has not seen and admired the marvelous vertical orb-web made by those gifted spiders which are called indifferently *Acaneus* or *Epeira!* Radii spaced at equal distances form the framework and connect it with the helix where insects are captured and which adheres tenaciously to the radii, and from the center where the latter converge there starts a guide line which, connects them with the ordinary retreat of the animal. In the case of the diademed *Epeira* (*Araneus diadematus*) this is a simple shelter formed by a few leaves loosely held together, while in the *Araneus quadratus* it is a silky shell-like structure with an opening beneath. Lurking at his post with one hand, so to speak, upon the guide line, the spider perceives the slightest tremor of the web. Has an insect been caught in the net? If so, he runs down the guide line until he reaches it, binds it fast, and slowly sucks its sweet juices, on the spot if it is small, but in his retreat if it is strong. At the time when the eggs are laid it fastens a cocoon packed with eggs to some plant in the vicinity; and when the young issue considerably later from the silky envelop they at once begin to spin threads which float in the air and carry the daring aeronauts hither and yon.

Silk and Spinnerets.—While silk does not play so important a part among all spiders they are all capable of producing it, at least at the period when the eggs are deposited. This property is characteristic of the chitinous animals and is observed in all their groups, at any rate among certain species, and in particular among the larvae or caterpillars of butterflies; but nowhere is it so general and so skilfully turned to profit as among the spiders.

The silk is a glandular secretion which may be extended into solid threads as it is emitted by the *spinnerets* from which it issues. The larvae of insects have usually only one spinneret which is situated upon the lower lip and from which issues only a single thread. But spiders possess several which are situated at the rear upon the ventral surface of the abdomen, and each of them bears a variable number of tubuar hairs or *fusules* which serve as vector conduits to an equal number of small silk-producing glands. Being produced by the partial or total fusion of all these elementary threads, the finished thread of the spider is complex in origin. The spinnerets which elaborate it are articulated appendices which vary in length. Four pairs are possessed by the *Piphistiidae*, which are exotic *Arachnidae* in which the abdomen has retained its dorsal segmentation, while they are reduced to two pairs in the closely related *Aviculariidae* or *Mygalas*. On the other hand the *Uloboras Dyctinas, Eresus* and similar forms preserve the totality of these organs, having, moreover, a modification of the spinneret of the first pair, which are contiguous, project only very slightly, and form together with their fusules a small protuberance called the *cribrellum*. The other spiders, which are by far the most numerous, lack this organ and, furthermore, possess only three pairs of spinnerets which are all grouped in front of the anus.

The silky threads are of different kinds but are usually cylindrical and are fine or coarse according to whether they result from the elementary threads produced by the fusules or from the coalescence of these: in the suspending cable of the orb-webs several coarse cylindrical threads may even be juxtaposed. The permanent helix of the orb-web of the Epeiras is entirely formed of a *viscid thread* which is composed of a solid cylindrical axis and viscid globules which hold fast the insects which are the spider's victims; these globules are very hygrometric and dissolve in rain water, while on the other hand, they slowly harden in the sun; it is by means of these that the web functions as a snare. Among the cribrellate spiders the same rôle devolves upon threads which are produced by the cribrellum and are made flocculent by a sort of comb, the *calamistrum* which occupies the penultimate joint of the hind legs; in the *Uloboras* which weave a horizontal orb-web, the *calamistral threads* which are rolled around an axial thread constitute the helix where the insects become entangled.

*Translated for the Scientific American Monthly from *La Revue Scientifique* (Paris).

MODELS SHOWING THE PROCESS OF WEAVING THE WEB OF EPEIRA SERICATA (SCLOPETARIA)

The spider started from a branch *a* (first plaque at left) and dropped to branch *b*, spinning a thread and fastening it. She then climbed on this thread to the upper branch, crossed over to the point *c* and dropped to a point *d*, making the strand as before. Then going to *e*, she fastened one end of the strand and spinning it behind her, went across by way of the upper branch to *f*. She then went to the upper branch and dropped to this *e-f* strand fastening the new line at point *h*. This pulled *e-f* up slightly. The next strand which she put in was from *i* to a point on the lower branch below *j*; pulling this line made another angle in the cross strand *e-f* as did the following line from *k* to *b*. These last two strands were fastened near the center by a bit of silk, and the remaining radii were put in by moving about on the foundation of the web. The next step in the operation was the laying down of the primary spiral which is shown in this second plaque and which ended at *l*. All these threads consist of smooth, tough silk which is not sticky. From this point on, the spider uses the sticky threads which constitute the real snare. The details of putting in the first of the sticky threads vary greatly. The spider started at *m* (third plaque) and its course may be followed by the letters to *v*. From *v* she continued in a regular spiral until the primary spiral of smooth silk was reached. She then cut away the outer portion of the primary spiral so that she might have more room for the snare. This process of cutting away the primary spiral and putting in the sticky spiral is shown in the fourth plaque about half finished. The last plaque shows the completed web with nearly all of the primary spiral removed.

Besides the calamistrum, which is proper to the Cribrellates, spiders possess organs situated at the end of the legs which are employed to grasp and to weave the thread. To begin with there are two toothed claws to which there is sometimes added a simpler accessory claw. Besides these organs one finds in good spinners bundles of pectinate hairs and, furthermore, a special hairy covering which is likewise employed in weaving. . . .

The Cocoons.—Ordinarily the cocoons of spiders consist of a simple envelope; this envelope, which is reduced to a few threads in the Mygalas of the genus *Ctenize*, becomes thick in the Epeiras but remains loose and flocculent, while in the *Drassus* it is so compact that the separate threads can no longer be distinguished.

The structure is often more complex; in the majority of the *Thomisas* and in the *Lycosas* the cocoon has two valves, lens-shaped in the former, and nearly spherical in the second. That of our beautiful *Argiope Bruennichi* is a double walled balloon which is truncated and fringed at one of its ends; its internal envelop is a sort of cylinder provided with a lid which lifts at the moment when the young appear; it is attached by a loose tuft to the external papyraceous wall which tears in the sunshine when the offspring is ready to come forth. This tuft is often accompanied by various débris in the double walled cocoon of our *Tegenaria.* Sometimes the cocoon is suspended by a pedicle as in the case of the *Agraeca brunnea* in which it is in the form of a graceful silken amphora covered with a layer of tempered earth; it is separated by a diaphragm into two stories, the upper being occupied by the eggs while the lower receives the young after they are hatched and before they leave the cocoon.

Each species has its own architectural method which varies with the character of the structure. The large *Lycosa* of Narbonne studied by Fabre, builds its cocoon in the open air outside the burrow which it inhabits. It first spreads a coarse net upon the ground, then in the center of this it weaves a disk of superb white silk thickened at the edges. The eggs are dposited all at the same time in the central depression, forming a projecting globe which the little creature covers with threads. It then separates by means of its legs this disk from the network beneath it and folds it back upon the globe, thus producing a sort of equatorial ridge which does not adhere very closely. When it has become free the rounded cocoon is about as big as an average cherry, the upper end from which the young issue being thinner than the lower part.

As soon as this work is finished the Lycosa attaches her cocoon to her spinnerets until the day when it opens and the young ones emerge, after which she carries her offspring on her back. All the *Lycosiidae* attach their cocoon in the same manner while the *Pholquas* the *Pisouras* and *Dolomedas* of our own land hold it against the breast attached to the venomous hooks called the *chelicerae.*

This method of protection which is very troublesome for the animal and none too good for the mass of eggs is ordinarily replaced by the *incubating chamber.* Among the *Bisauras*, however, the second method merely follows suit upon the first; after having carried the cocoon around for awhile these wandering spiders weave a huge bell-shaped structure where they deposit them and where they stay on guard after the young appear, remaining for some little time afterwards. Other wandering spiders make use of the second method at the beginning; thus the *Thomisiidae* of the genus *Misumena* establish a hammock where they watch over their mass of eggs and in the family of the *Clubioniidae* the *Micrommata* weave a large incubating chamber of silky tissue, constructing it upon bushes or trees.

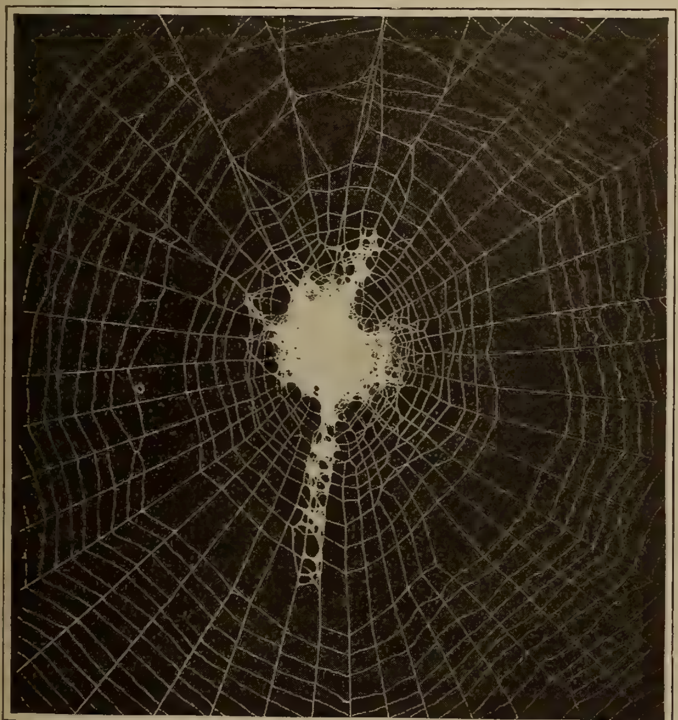
There is reason to believe with Pocock (1895) that the spider "by a slight modification of its intelligence has been led to extend to itself the protection" which it afforded first to its eggs and that in this manner the incubating chamber has become a permanent abode. Furthermore, this transformation is effected according to two divergent manners, whose point of departure is found in the family of the *Drassiidae;* some of these spiders confine themselves to the construction of an incubating chamber, but Simon (1892) notes that others such as the *Drassodus lapidosus* make of this chamber "a large, residential shell, where they pair with each other and stand guard over their eggs," while the species of "the group of *D. troglodytes* do not construct the shell but either stand guard over their cocoon on the open ground or else dig a sort of little burrow which they make use of as their retreat." These are the two sorts of industries proper to the tribe of spiders: the *burrow* which serves at once as a shelter and as an incubating chamber; and the *residential shell* which extends into a web but which does not always continue to serve to protect the eggs.

The Burrow.—The earth digging industry has been developed independently in two groups which differ greatly from each other: the *Lycosas* and the *Aviculariidae* or *Mygalas*. In the first we can observe all the stages between an existence which is frankly wandering and that of an almost entirely sedentary life: "The small species of the genus *Lycosa*," writes Simon (1897), "found in meadows and woods pursue their prey by the chase; some of them (*L. nemoralie* . . .) build no retreat, others take refuge at the egg-laying period beneath a stone and surround themselves with a little rampart of earth (*L. pulverulenta* . . .), while still others (*L. fabrilis*) dig a shallow shelter which is often garnished with threads; those which live upon shifting sand (*L. perita* . . .) adorn their dwelling with a little silky sheath which is very slack and is agglutinated . . . the large species dig a burrow which is often quite deep and is vertical as a rule . . . ; its yawning orifice is surmounted by a little circular or semi-circular wall which has been compared to a bastion." In the group of the *Tarentula lycosas*, at least, the digging habit although definitely instinctive develops only with age: Fabre has proved, in fact, that the young of *Lycosa Narbomnensis* are wandering spiders during the greater part of their first year and do not dig a shelter till the coming of autumn; he has observed also that the animal establishes this retreat little by little, that it never abandons it, and that is it incapable of making a second one when dislodged from the first, in which case it becomes wandering unless provided with another. This shelter is not built of masonry but is covered with a little silk, at least in its upper portion.

The *Aviculariidae* and the closely related *Atypus* possess in a very high degree, the skill of the miner they also know how to construct masonry, for before weaving for their retreat an envelop of silk they rough-coat it and make it impermeable by means of a mortar made of earth and saliva. The galleries of these *Arachniidae* differ greatly according to the species, being sometimes in the form of simple pits more or less inclined as in the mason *Migala* (*Nemesia comentaria*), sometimes expanded into a pocket in the lower portion as in the *Atypus Abboti*, and sometimes having a lateral gallery of refuge as in the *Nemesia Meridionalis*, the *N. badia* modifies its burrow in the autumn, making a second orifice in it. This seasonal habit becomes a custom in the *Stothis astuta* which, according to Simon (1889), digs an underground gallery in the form of an arc in the shifting soil. Many exotic species make their galleries in wood, perforating the bark for this purpose.

A young English observer, Moggridge, devoted the last days of his too brief existence to the study in the vicinity of Nice of the manner in which our *Mygalas* establish their retreat. "The legs" he says (1873), "are not employed in the digging and the palps are but little used; the principal instruments employed are the *Chelicerae* with their hooks. As soon as a little earth has been detached and collected the spider comes to the edge of the hole and there deposits a full mouthful of material, spreading its *chelicerae* apart and shaking them up and down so as to let fall the ball of earth which it has held between the hooks and the buccal organs." Better to perform their work certain species have a sort of rake upon the basal joint of the *chelicerae* near the hook; others, according to Simon, use the hind legs to push off the earthy particles detached by the *chelicerae*. The earth dwelling *Lycosas* also work with the *chelicerae* but they always lack a rake, and according to Fabre they hold the pellet of earth which they are carrying with the palp.

Fabre has likewise studied the manner in which the *Lycosa* of Narbonne builds the bastion which surrounds the opening of its burrow. It forms it "of little pebbles, bits of wood, scraps of dry leaves, etc., the whole dexterously interlaced and cemented with the silk." And again it is the *chelicerae* which are employed. Many *Lycosas*, especially among the American species perform similar labors. McCook reports (1889) that the *Lycosa arenicola* builds a bastion in the form of a chimney with small bits of straw or wood and that . . . at the base of this edifice it builds a little wall of grains of quartz. More skilful still, the *L. Carolinenses* executes a neat bit of basket work; it curves, interlaces and fastens pine needles, so as to form a sort of bastion in the shape of a bird's nest upside down. Sometimes the bastion is a mere prolongation of the silky inner tube, as in the *L. tigrina* in which it spreads into a cone and inclines towards the ground,



Courtesy Amer. Mus. Nat. Hist.

WEB OF THE METARGIOPE TRIFASCIATA

This and its larger relative Miranda aurantia are among the most conspicuous of the orb-web spiders.

WEB OF THE ARANEA TRIFOLIUM

A signal line runs from center of web to the tent which it makes of leaves and silk some distance off.

and in the *Atypus Abboti* in which it is a long tube fastened to the trunk of a tree. . . . Simon also mentions an Algerian *Mygala* (*Leptopelma elongata*) in which the upright bastion has the form of a spreading funnel. . . .

The bastion is an observation post but above all it is a protective edifice. Fabre observed that the Narbonne *Lycosa* frequently closes the orifice of its nest by a silken ceiling, which it perforates and throws to one side when it wishes to make its exit; he supposes that the habit of building a bastion may be derived from this. However this may be, Mary Treat (1880), has shows that such edifices may afford effective protection to the spider. Like the other earth dwelling *Lycosas* the *L. tigrina* razes its bastion in the autumn and closes its shelter with various materials; it also closes it at certain periods during the summer but at this time it leaves the edifice untouched, covering it with leaves, moss, or grass, so as to entirely hide it. This is at the moulting season, and later when it is about to spin its cocoon the spider also shuts itself in in this manner, but this is also in the midst of August at which time its activities should be very great. However it is in the month of August that the *Elis 4 notata*, the bitter enemy of the *Lycosa*, sets forth upon the chase, and it is probably to protect itself against the attacks of this predatory wasp that the spider closes its dwelling. The young *Lycosas*, which are scorned by the wasp, never take this precaution; as for the adults they seem to foresee some return to the attack, for even after the season of the *Elis* has passed, when they have opened their bastion, they leave attached to the edge of it a bit of foliage or the like which they make use of as a swing door, which they pull shut after them when danger threatens.

Courtesy Amer. Mus. Nat. Hist.

BIRD-SPIDER AND ITS EGG SACK

This brings us to the operculum or lid which serves to close the burrow of some *Lycosas* and of most *Mygalas*. That of the cunicular *Lycosa* of Algeria protects a retreat which lacks a bastion; it is simply a disk of earth whose solid particles are held in place by a silky network, which covers the lower surface and spreads into a homogeneous layer. It is kept in place by a few threads which do not make an elastic hinge so that it is found cast aside when the spider makes its exit.

The opercula of the *Mygalas* exhibit a more perfect form of industry and their nests belong to two types which have been called by Moggridge wafer-nests and cork-nests. The lids of the former are thin and rest upon the orifice without penetrating it and are mainly silky, but are often encrusted with earth; when they are rigid in character the hinge is remarkable for its great elasticity. The simple burrow of our *Nemesia Simoni* is closed by a soft operculum. The lids of cork nests always penetrate the orifice fitting it exactly like the stopper in a bottle; they are made of alternate layers of earth and silk, have a more or less perfect hinge, and have a thick covering of silk on the underside; they are found in many species in the neighborhood of the Mediterranean Sea. . . . The simple burrow of the *Nemesia Eleonora* observed by Moggridge has two lids, the outer one of the wafer type and the inner one of the cork type; the same thing is seen in the bifurcated burrow of the *Nemesia Meridionalis* in which the operculum is immediately in front of the bifurcation. The bifurcated burrow of a Venezuelan *Mygala* (*Rhytidicolus structor*) . . . has three lids all of the cork type, one outside, the second have the middle of the principal gallery, and the third at the orifice where the latter opens into the bifurcation.

The layer of silk which lines the inside surface of the opercular of the cork type sometimes has a marginal series of holes which enable the spider to hold the door shut by inserting its claws. Moggridge observed that when one knocks upon the lid of the mason *Mygala* the spider sometimes remains perfectly quiet but sometimes on the other hand leaves the bottom of its retreat in order to hold the door tight shut. When the latter is forcibly opened one sees the *Mygala* with all its claws hooked into the lower cushion of silk. . . . The spider thus holds itself across the pasage way with its back downwards and its head opposite to the hinge. This instinctive act is a reflex action, but it was without doubt occasioned by intelligence when it originated. The inside operculum of the *N. meridionalis* serves to close the lateral branch when it is drawn inside and the principal gallery when it is thrust outward. The *R. structor* undoubtedly performs two similar maneuvers, for its two opercula at the extremities open from within outward, while that in the middle opens in the opposite direction. It is evident that the instinct of these spiders is as remarkable as their industry and must have undergone a long process of development.

The Web.—As Pocock points out, while the operculum of the earth dwelling species is the result of a need of protection the web of the aerial species was evolved by the need of obtaining prey. It is at first a simple shell for habitation and the deposit of the eggs as is seen in the Saltiques but this shell sometimes assumes quite large dimensions and becomes an observation post whence the spider departs to follow the chase. An example of this is seen in the "Clotho" (*Uroctia Durandi*) studied by Fabre; this southern species constructs a reversed cupola underneath stones, almost as large as half a mandarine. "The edge of the cupola radiates into a dozen angular prolongations whose expanded point is attached to the stone. Between these suspension cables there open an equal number of spacious inverted arcades. A flattened roof stretched between the cables of attachment closes the top of the dwelling . . . all the arcades of the edge open underneath the roof" save for one which is similar to the others except that it is in the form of a two-leaved door which the spider can open or close. It is through this door that it departs for its nocturnal chase, but it is in the interior of the chamber that it plants its cocoons, five or six in number which it stands guard over from October to the following June without taking food. When the young ones have taken their departure the mother abandons this dwelling and goes elsewhere to build another.

In spite of its great size and the numerous *trabesulae* which attach its dome to the ground beneath it, the chamber of the Clotho is not employed to capture its prey. . . . Our little *Chiracanthium Carnifex* builds upon the panicles of oats or

in leaves an ovoid shell about the size of a pigeon's egg; this shell is thick, opaque, very smooth inside, open beneath and connected with the adjacent plant organs by threads; the spider remains ambushed within in order to seize the insects which frequent the stalks of grain or which become entangled in its threads. Thus the dwelling is not only a hunting post but to some extent an instrument for the purpose of capture; it also serves as an incubating chamber and the spider closes it up to stand guard over the cocoon and await the birth of its offspring.

In the family of the *Theridiidae* a true web makes its appearance—quite irregular to be sure and with very large meshes comparable to a certain extent to the "fixator" network of the Clothos and of the *Chiracanthium* but much more extensive and well fitted to be used as a trap. In our *Theridium Riparium* it extends in every direction around the chamber, which it helps to hold firm. This chamber is conical, open beneath, and covered on the outside with small stones or earthy or vegetable débris which make it resemble the tube of the *Phrygana* or of the *Psyche*. This *Theridium* which is sedentary like the *Chiracanthium* captures its prey by entangling them in the network; and when the period of egg laying arrives it fastens its little globular cocoon inside the point of the cone. Some of the *Theridiiae* content themselves with constructing an incubating shelter in the midst of their web and some of them, such as the *Theridula*, attach the cocoon to a spinneret like the *Lycosas*. The latter leads us to the industry of the *Pholqua* which construct a web similar to that of the *Theridiiae* but which remains lying back downward upon this web carrying its cocoon upon its breast attached to the *chelicera*.

Being a network annexed to the dwelling chamber the web is perfected in two different manners—*a sheet of close-woven tissue* and the *orbicular network*.

The first of these methods is exhibited in two forms of the same family—the *Tegenaria* and the *Agalenas*. In both of these the chamber of inhabitation which is also a look-out post has the form of a funnel with a double orifice; the circumference is large and is continued by a sheet of close woven tissue in which end the threads of the network are employed for capturing the prey. When the time for laying her eggs arrives the spider leaves the web and plants her silky cocoon somewhere in the neighborhood. Our *Agalena labyrinthica*, which establishes her web upon the grass, also constructs her snow-white chamber with two exits, where she perishes in the autumn in the midst of her watch over the mass of eggs from which the young will not emerge until the spring. The large spider found in cellars and on walls (*Tegenaria parietina*) also stands watch over her eggs in an incubator hammock, but the other *Tegenaria* content themselves with placing their cocoons and afterwards return to their webs. Among these their predatory habits predominate over the care of their progeny; we shall find the same thing to be true in those species in which the orb-web exhibits its most perfect type.

The various stages of the development of the orb-web may be observed in the large family of the *Argiopiidae*. The *Linyphia* leave an irregular network like that of the *Theridions*, but this network supports a flat web in the *L. Costate* and two dome-shaped webs in the *L. Communis* in which we see an indistinct orb arrangement make its appearance. There are likewise two superposed webs in the *Cyrtophora Basilica* studied by McCook (1889), but while the lower web is flat the upper one is a dome with an evident orbicular arrangement. Like the preceding ones this species remains in the structure without a residence shell and places its eggs there, the latter being connected in the form of a string of cocoons.

In the *Theridiosoma gennosum* (*Epira rediosa* of McCook) the web is stretched vertically, being sustained by radii which are fused together towards the center and without a spiral thread except at the periphery where the rudiments of one may be seen. The spider does not remain within the web, but stays upon a taut guide line which gives the web the appearance of a cone. The vertical web of the *Zilla* is an incompletely regular orb in which the radii and the helix are interrupted in a triangular segment traversed by the guide line; the latter leads to a dwelling shell in the form of a bell or thimble. The large tropical spiders of the genus *Bephila* and our own *Argiope* do not stretch a guide line; the former remain in a close woven network which occupies a hollow at the upper edge of their web and the second stay at the very center of the structure, which is sustained by one or two zig-zag radii, the *Stabilimentum*, formed by a tuft of interlaced threads. In both, moreover, the web is almost vertical and forms a perfect orb as it does also in our *Araneus* or *Epeira* which also have a guide line at the end of which is a dwelling shell which serves them for a retreat and an ambush during the day. In these latter forms the cocoon is rarely placed within the web being generally found in the vicinity and receiving no care. Here again the original maternal instinct which forms the point of departure for arachnean industry is dominated by the predatory habits.

Courtesy Amer. Mus. Nat. Hist.

AN ENORMOUS TROPICAL SPIDER WITH A SPREAD OF 7 INCHES AND BODY 2 11/16 INCHES LONG (HORNOEMMA SP.)

The most difficult but not the most delicate work in the making of an orb-web is the establishment of the suspending cable which stretches between two points at a distance from each other and supports the whole structure. Sometimes the spider fastens its thread at one of these points and then repairs to the other where it stretches and fastens the cord which has issued from its spinnerets during the course of its journey. But this process is not applicable over all sorts of *terrain* and is even practically impossible when the two points are separated by a stream of water or by any other insurpassable obstacle. In this case the spider stations itself or suspends itself at one of the points . . . and emits a thread which is carried by the wind until it attaches itself at another elevated point. According to Fabre the process may differ somewhat, however: the spider may suspend herself but soon thereafter reascends by her thread; the latter then forms a loop which is stretched out and fastened by the wind as in the preceding cases. In any case the spider knows quite well when the attachment has occurred. She then stretches her cable, and runs back and forth across it several times in

order to multiply the number of threads and thus render the cable more firm. The next thing is to establish another side to the framework: the spider suspends herself again, then reascends by means of her thread, follows the cable to the opposite end, and then seeks a suitable point further down where she stretches and fastens the thread emitted in the course of the journey.

In the same manner, or by simply walking from one point to another a diagonal thread is established which serves as the first radius of the web. Upon this diagonal line a point is chosen to be the center of the structure; the spider attaches a second radius at this point and then proceeds to walk to the framework where she fastens the other extremity, after which she returns in the opposite direction to stretch this thread and make of it a definite radius; the excess length is reserved at the center to form a cushion. Now at one side and now at the other, in order to render the structure more stable, the spider attaches new radii by the aid of those already established. When finished the radii are spaced at equal distances; they vary in number according to the species; Fabre counted twenty-one in the angular *Epeira* and thirty-two in the fasciated *Argiope*.

Resting upon the cushion the spider now revolves repeatedly about her own axis, attaching to the radii a central helix whose inter-radiary elements are straight lines. Then she advances a little farther and begins to establish a second similar helix which extends to the framework. This second helix is permanent in the *Nephilae* and temporary in the *Argiopae*, the *Epeira* and most other forms. Since it consists of cylindrical threads it is not very suitable for purposes of capture. Consequently as soon as it has carried it to the framework the animal returns along this helix, placing between its spirals a new helix whose elements are composed of threads bearing sticky globules. This helix constitutes a marvelously effective trap. In establishing it the spider takes for a support and scaffolding the auxiliary helix; but as the work proceeds the latter is destroyed except among the *Nephilae*, in which it is retained to give more solidity to the structure.

Upon arriving at the narrow open space which separates the auxiliary helix from the small central helix, the spider returns to the cushion which has now become useless and reduces it to a compact mass which she proceeds to swallow and digest to provide new threads. At this place the *Eperia* weaves a loose network while the *Argiope* makes a sort of shield of microscopic threads which serves as a sort of support for the look-out post; in the latter the *stabilimentum* is a mere prolongation of the shield and exhibits the same structure.

Spiders that have a cribellum replace the threads that bear globules by calamistral threads as seen in the *Uloboras* which make an orb-web which is similar to that of the *Argiope* but is extended horizontally.

The orb-webs and especially those of the *Epeira* represent the most perfect type. Pocock has shown how their radial structure indicates to the animal the very point at which they are disturbed and how the arrangement of the spirals sustains them though leaving them almost invisible, without increasing their weight to such a point as to involve breaking by means of rain; furthermore, the elements of the helix cross the rays at such an angle that they give to the structure a maximum of solidity with a minimum number of threads, so that in constructing these orbs "an *Epeira* economizes both time and silk and makes her net as resistant as need be while as delicate and nearly invisible as possible."

Psychology of Spiders.—In order to arrive at such a degree of perfection and to be able to adapt themselves so well to their industrial needs our *Epeiras* must have gradually developed through various stages from the epoch when their ancestors contented themselves with weaving a simple cocoon. Among them, as among the spiders which weave sheets of web and among the earth dwelling species the comparative method of study has enabled us to reconstruct in a measure the series of these stages which has led us to the present form of the industry. . . . But it must be admitted that our knowledge of arachnean psychology still leaves us in ignorance as to the manner in which such a great degree of progress has been accomplished.

It is not always easy to decide between the parts played by intelligence and by instinct, but apparently the former is low in degree and dominated by a strict automatism. . . . The *Nemosculus Laurae* establishes in a vertical position near her orb-web the inverted cone which serves as her retreat; this is constructed by starting with the periphery of the orifice but "from the very beginning the threads which hold the orifice open are placed in position and a few temporary threads hold the upper portions of this ring;" is it possible to ascribe to pure automatism or to mere reflex action so judicious a bit of architectural scaffolding? Undoubtedly the psychology of spiders offers a vast field for observation and experiment.

Nevertheless, thus far, research has demonstrated but little intelligence among spiders. Fabre reports that the *Nephila* of Madagascar, nightly renews the viscid threads of half its web and regularly alternates this destruction and remaking of one-half and the other. But if the new made half be injured or destroyed the spider pays no attention but automatically destroys and remakes the part remaining intact. Fabre

Courtesy Amer. Mus. Nat. Hist.
NEST OF THE TRAP-DOOR SPIDER

has noted that our native species are incapable of repairing their web when it is injured; he has seen the angular *Epeira* collect the fragments and swallow them, starting from the beginning to make a new one; he has also seen the same species reunite by a simple thread the two halves of a web which had been split along the diameter or else remain motionless in the center of the network whose helix had been destroyed while the radii remained intact. . . .

Our *C. carnifex* seems to take better care of its dwelling. "If the wall is torn it repairs it without leaving it; if the nest be cut into fragments it unites these with a remarkable patience." But we are here concerned with maternal cares and these are nearly always automatic among spiders. . . . Warburton has observed that when our labyrinth *Agalena* has finished constructing its complicated incubating chamber it remains there even if the eggs are removed ;and Fabre states that Thomisa readily accepts the nest and cocoon of another member of the same species, while the Narbonne *Lycosa* glues to its spinnerets as if it were a pouch of eggs, a ball of cork, paper or thread, and finally, that the same spider will readily accept other offspring when deprived of her own. The Peckhams even report that a similar spider several times accepted a ball of lead three times as heavy as her pouch of eggs, but covered with the envelop of the latter. Fabre has interpreted these curious phenomena by saying of his Thomisa "Provided it has a piece of satin under its legs does not perceive its mistake." . . . But it may be observed in this connection that many mammals and birds can be similarly

deceived . . . does not one see hens lavish their maternal warmth upon imitations of plaster or stone? In short our spiders are attached to their cocoon or their nest and not to their progeny. This explains the labor of the *Chiracanthium in repairing its injured shell.* Lécaillon has noted that this species is more attached to its nest than any other, that it recognizes the nest after an absence of a week, and spares no pains in the effort to re-enter it, and that it defends it with fury when one tries to remove it. . . .

Some authorities have seen a proof of intelligence in the behavior of certain *Mygalas* which hide their operculum by coverign it with bits of vegetation. It is possible that this habit originated in an intelligent act, but it has certainly become entirely mechanical and is even of disadvantage to the animal at times. Moggridge says: "I have removed a little clod of mossy earth about three inches square and two inches thick from the surface in the terrain where there was the orifice of the burrow and the cork-lid of the *Nemesia cementaria.* Six days later I found a new operculum upon which the *Mygala* had planted moss found nearby. But this actually served to attract attention instead of hiding the burrow since it was in the midst of the little area of brown earth which I had left when removing the clod."

Does all this mean that spiders are entirely lacking in intellect? Not at all. They prove that they possess memory by the recognition of their nests; many examples show that they are capable of learning . . . , and they necessarily display a certain degree of discernment when they establish the bases of their shell or nest. And it is by making use of these faculties that they have been able to display plasticity in their habits and undergo an evolution in their industries. At the present time they are doubtless quite as capable of evolution as in former times, but this tendency escapes our notice because of the automatism which dominates it. We are particularly struck by the extraordinary rôle played by touch in their automatic manifestations. Spiders nearly always perform their labors at night and it is merely by touch that they are able to recognize whether their cables are sufficiently taut, their radii properly spaced, and the spirals of the helix regularly placed. With their legs and their palps they search for contacts and measure distances and the sensitiveness of the spinnerets reveals to them the moment when their silken thread is properly attached. They seem to work as if blind, being largely guided by simple tactile reflexes.

Aeronautic Spiders.—Young spiders and in some cases adults also owe their faculty of crossing space like aeronautics to a peculiar form of tactile sensibility. This curious phenomenon was pointed out in 1670 by Martin Lister and has since been the subject of numerous observations including those of Darwin. During the cruise of "The Beagle" when the ship was sixty miles from land in the mouth of the La Plata, he saw the space around him filled with floculent webs. "A large number of little spiders about one-tenth of an inch long were hooked to the webs. I suppose there were thousands surrounding the ship. When the little spider came in contact with the rigging it was always hanging to a single thread and not to the flocculent mass. The latter seems to be produced by simple threads. These spiders were of a single species, but of both sexes, with their young. . . . While I examined some of them hanging from their single thread it repeatedly happened that the lightest breath of wind carried the spider out of sight in a horizontal direction."

Three weeks later Darwin saw members of the same species climb upon a projection, lift the abdomen, emit threads, and bringing their legs close together sail rapidly away. In his opinion it was the hot air rising from the ground which carried away the little creatures suspended from their threads.

Not a line of this account but gives an exact idea of the manner in which the spiders manage their aeronautic travels. The sole point which remains somewhat obscure is the method employed by the animal in emitting its thread and suspending itself therefrom. This differs in different species. According to McCook the wandering spiders . . . climb up to an elevated point, place their heads in the direction of the breeze, lift the abdomen, and spreading the fusules and spinnerets apart, emit a quantity of fine threads which follow the direction of the wind. Arched upon its legs the animal at first resists this force, which tends to lift it, and then when the threads are long enough it allows itself to be carried away with its back downwards and its legs pressed against the body. It can also climb along this floating rigging which it shortens and gathers into a ball against its ventral surface or which it elongates by the functioning of its spinnerets. . . .

The method seems to differ in the case of the orb-web spiders, in which it much resembles that which preludes the establishment of the suspending cable. Fastened by one end and the other continuously with the spinnerets the ropes of the aeronauts take the form of a loop under the influence of the current of air which carries them away and stretches them; and when their ascensional force is sufficiently great they are severed near the point of attachment. . . . Details seem to vary in different species or individuals. According to McCook the spider suspends itself by a long thread which breaks under the action of the wind; according to Fabre the fasciated *Argiope* suspends itself repeatedly, reascending to make a collection of threads. . . . "Gently lifted by the ascending currents which rise from the ground heated by the sun, this thread rises, floate, undulates and strains at its point of attachment. Finally it breaks and disappears in the distance bearing with it the creature that spun it." . . .

* * * * *

However the manner may differ spiders behave like aeronauts making use of a kite: they require a current of air to carry away the thread which suspends them and this current always results from differences of temperature in the different strata of the atmosphere. In Favier's experiments this current was produced by the temperature of the observer's body and when he increased his distance the little parachute descended. Consequently the flights of spiders may occur only on fine, warm days when there is a gentle breeze, or when the superheated ground produces an ascending current of air. When favorable weather coincides with an abundant hatching of young spiders, as happens especially along towards autumn, the ropes of our aeronauts float in large numbers over plants and in the atmosphere where they compose those silky ribbons commonly known as the *threads of the virgin.* Sometimes individuals of large size also fly in this manner: "The largest orb-web spider which I have ever seen floating in the air," says McCook, "was a big *Epeira domiciliorum* nearly a quarter of an inch long. After having floated above a field it crossed a road and attached itself to the top of a young tree. It was never more than 20 feet high, but I had some trouble in following its flight with my eye." But young spiders are able to reach a much greater height, for the same biologist tells us that he found *Epeiras* spinning their threads at the summit of the dome of St. Peter's.

Most spiders, but not all, are capable of this sort of aerostation. . . . This faculty is eminently favorable to the survival of the species, since our *Arachnidae* are born in groups in a cocoon and are disseminated in space like the winged seeds of plants, thus more readily finding favorable places of existence. McCook explains in this manner the vast area of distribution of a large tropical spider, the *Heteropoda venatorie* which is found without perceptible variation in all those continental regions where the trade winds blow.

In fine, the flight of spiders is a phenomenon in which the tactile sensibility of the spinnerets plays a great part, since this indicates to the animal the amount of ascensional force at its disposal; it involves a certain degree of discernment since the aeronaut can prolong its ascension or direct it towards the earth at pleasure by elongating its cable or by gathering the latter into more or less of a ball, but it is difficult to tell the precise degree to which these intelligent acts have assumed an automatic form in different species.

Science and National Progress

Edited by a Committee of the National Research Council

Dr. Vernon Kellogg, Chairman, Dr. R. M. Yerkes, H. E. Howe

The National Research Council is a co-operative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the natioanl strength and well-being.

FOOD AS A NATIONAL INTEREST

By Vernon Kellogg.

ABOUT a quarter-century ago the great Polish economist, Jean Bloch, declared in his famous book, "The Future of War": "That is the future of war, famine, not fighting." And while this epigram was revealed by the World War of 1914-1918 to be but a half-truth, as most other epigrams are, yet the element of real truth in it was abundantly proved. If the Allied and American military effort had not been successful in the fall of 1918, as it was, famine would have been successful in 1919 in ending the war. Even as it was famine played an important part in making the military victory possible at the time it occurred.

So insistent throughout the war was the food problem of all the nations engaged in fighting and, incidentally, of many nations not fighting, especially the European neutrals, that Food Ministries, Food Controllers and Food Commissions were established by all these harassed governments, and the governmental and popular attention to food matters was hardly less than that which was given to military matters.

In all these governmental efforts to administer food most economically and effectively for the sake of the national physical strength and spiritual morale—for starving is a great weakener of morale as well as of body—and in all the great private relief undertakings, the food administrators early found themselves face to face with the necessity of knowing as much as they could of the scientific basis of rational food use. And in trying to find out what this knowledge is, the various responsible administrators and their advisors soon discovered that this scientific knowledge is anything but complete: there are great gaps in the necessary knowledge and great differences of expert opinion about many matters which are a part of the alleged knowledge as far as it goes.

So serious was the need of bringing to bear on the situation all that science could contribute that even during the stress and rush of war the Allied governments and America united in forming an Inter-Allied Scientific Food Commission composed of leading physiological chemists and special food and nutrition experts from each country. This Commission met at different times in the spring of 1918 in Paris, Rome and London, again in Paris in October, 1918, again in Rome and Naples in December, 1919, and finally at Brussels in May, 1919. The results of the Commission's meetings are included in various reports which were handed promptly to the Food Ministries and other food-controlling authorities of the various countries represented on the Commission and much use of the findings and recommendations of the Scientific Commission were made by the authorities on whom fell the responsibility for the allocation of food quantities to the various Allied countries from the existent and obtainable supplies.

Among the interesting points taken up by the Commission were: First, the determination of the most desirable daily ration for the "average man" from the point of view of total calories necessary and the best relative proportions in this ration of proteins, fats and carbohydrates; second, the determination of the proper coefficients to apply to infants, children, and women and men doing different kinds of work, that is, no work, light work, heavy work, etc., so as to define their food needs in terms of those of the "average man"; and, third, the determination, on a basis of the varying make-up of the population of the different countries, what coefficient should be used for each country to express its total needs in terms of the "average man" ration.

As for the first point, it was agreed that a daily ration composed of a variety of foodstuffs, including meat and bread, providing 3,300 calories, or energy units, was proper for the "average man," and that this ration should include in its make-up at least 75 gr. of fats. It was agreed that in practically any mixed ration provided that would produce 3,300 calories a sufficient supply of protein matter would almost certainly be included, so no specific recommendation as to protein content was made. The same applies to the carbohydrate content.

As for the second point, the following coefficients were agreed on:

Age and Sex.	Coefficients of Conversion into the "average man."
0 to 6 years (both sexes)	.5
6 to 10 years (both sexes)	.7
10 to 14 years (both sexes)	.83
14 years and above (women)	.83
14 years and above (men)	1.00

As for the third point, the determination of the coefficients to be applied to the total population of the different countries taking into account the relative proportions in each population of men, women and children, the following were decided on:

United Kingdom	.835
France	.845
Italy	.826
United States	.84

That is to say if we take any one country, as England, for example, it is believed that an average 100 of the population equals from the food needs point of view 83.5 "average man."

Many other important problems were taken up, but most of them refer to conditions which only exist in times of war and hence are of less present interest. One, however, is of perennial interest. It is that of the most advantageous rate (extraction rate) of milling the various grains when it is desirable to have the available supplies of these grains go as far as possible in bread-making, *i. e.*, produce as many loaves of wholesome bread as possible. This is primarily a matter of special interest in times of grain shortage, but it also touches the moot question of "whole wheat" bread versus bread made from flour of lower extraction rate. It would obviously "stretch" the grain more if 100 per cent flour (containing all the "offals") could be used in times of grain shortage, but the Inter-Allied Committee of representative physiological chemists and nutrition experts decided that even in times of great shortage wheat could not advantageously be milled at an extraction rate higher than 85 per cent for use in making bread for the whole population. For certain individuals there is little doubt that a higher rate would not be disturbing; for others it is preferable to use even a lower

rate. For rye the recommended rate is 70 per cent, for barley, 65 per cent and for maize, 85 per cent.

At the Brussels meeting in May, 1919, which was the last held by the Commission, it was decided that as the war had passed and the Commission had been formed as a war organization it should dissolve itself. This was done by formal resolution, to which was attached an equally formal and positive recommendation that a permanent international scientific food commission should be established to take its place. And it was further decided to attempt to have such a committee function in some recognized affiliation, perhaps like that of the International Red Cross Societies, with the League of Nations. Nothing has been decided about this as yet, but it at least shows how convinced were the governments whose official delegates had represented them on this war food body that there is need of a continuing study of the science of food use in relation to its larger aspects, national and international.

In the meantime separate action has recently been taken by the National Research Council of this country to initiate and carry forward work on certain food and nutrition investigations which are of pressing importance. This action has resulted in the formation of a special Committee on Food and Nutrition of the Council's Division of Biology and Agriculture. The Committee is composed of fourteen members who represent the physiological chemists, the experts in both human and animal nutrition, and the home economics students of the country. The list of members is as follows:

Chairman of the Committee, and of the Sub-committee on Human Nutrition, J. R. Murlin, Professor of Physiology and Director of Department of Vital Economics, Univerity of Rochester; Chairman of the Sub-committee on Animal Nutrition, H. P. Armsby, Director of Institute of Animal Nutrition, Pennsylvania State College; Carl Alsberg, Chief, Bureau of Chemistry, Department of Agriculture; Isabel Bevier, Director of Department of Home Economics, University of Illinois; E. B. Forbes, Chief, Department of Nutrition, Ohio Agricultural Experiment Station; W. H. Jordan, Director, N. Y. Agricultural Experiment Station; Graham Lusk, Professor of Physiology, Cornell University Medical College; C. F. Langworthy, Chief of Office of Home Economics, Department of Agriculture; F. V. McCollum, Professor of Biochemistry, School of Public Health and Hygiene, Johns Hopkins University; L. B. Mendel, Professor of Physiological Chemistry, Yale University; R. A. Pearson, President of Iowa State Agricultural College; H. C. Sherman, Professor of Food Chemistry, Columbia University; A. E. Taylor, Rush Professor of Physiological Chemistry, University of Pennsylvania; and A. F. Woods, Botanist, President of Maryland State College of Agriculture.

The problems which have already been formulated by individual members and sub-committees of the Committee and to which it purposes to give immediate attention, include those of the comparative food values of meat and milk and of the conditions of the production of these foods in the United States together with the whole general problem of animal nutrition; the nutritional standards of infancy and adolescence, and other similarly large and important problems.

A subject to which the Committee is giving serious consideration is that of the establishment in this country of a National Institute or Laboratory of Human Nutrition. Each of the delegations to the Inter-Allied Scientific Food Commission is recommending to its government that a national laboratory for the study of the problem of human nutrition be established in its country. If this can be done and an International Scientific Food Commission can be established in connection with the League of Nations, which can correlate the work of the various national institutions, a great and most needed advance in food science can be made. Not only can advance be made in finding out more of the actual character of various food stuffs and the actual needs of human beings of different ages and sex existing under varying conditions of work and disease or abnormality, but advance can be made in knowing more exactly the national production and consumption and waste of food in different countries, and in planning for more economical international food exchanges and general relations. And such a series of national food laboratories or institutes could also help materially to educate the people of their various countries in wise and economical ways of food use.

THE CERAMIC INDUSTRIES.

The National Research Council and the American Ceramic Society have formed a special committee on Ceramic Research in affiliation with the Division of Chemistry and Chemical Technology of the Council. This committee is composed of Albert V. Bleininger, of the Governmen Bureau of Standards, Chairman; Professor E. W. Washburn, of the University of Illinois, Secretary; Arthur L. Day, Second Vice-President of the Corning Glass Company; Robert B. Sosman, acting director of the Geo-Physical Laboratory of the Carnegie Institution at Washington; and Homer F. Staley, of the Bureau of Standards. The first efforts of the committee are being directed toward the establishment of a group of university research fellowships in ceramics whose holders are to devote themselves primarily to the investigation of fundamental scientific problems in the ceramic industries, rather than to the "works problems" which, though equally urgent in their need of solution, can be attacked more advantageously perhaps in the ceramic plants themselves, and, anyway, have back of them still unsolved scientific problems.

The committee has recently prepared a report which contains much matter of general interest as throwing light upon the present-day status of the ceramic industries.

These industries, which include brick and tile making, and general crockery and glass manufacture as well as that of ornamental potteries, although among the earliest ones developed by man, have been among the last of our great manufacturing industries to rise from the status of empirical art to that of applied science. This is doubtless in a great measure due to the fact that the industry, being older than the science, had necessarily to develop in a purely empirical fashion. The many rule-of-thumb methods and so-called trade secrets which are the inevitable accompaniments of a complex industry, representing the accumulated experience of many generations of workers, have, in the past, naturally bred a conservatism not favorable to new ideas and methods or to a ready appreciation of the value of scientific research or the advantages of scientific control over its materials, processes and products.

In sharp contrast to the painfully slow development of these ancient industries we have those exclusively modern industries, such as the synthetic dye industry whose foundation was made possible by the discoveries of modern science and whose industrial success and marvelously rapid growth is almost entirely the fruit of highly organized scientific research with methods of scientific control at every stage of its operations. An English scientist is authority for the statement that the capital, large though it has been, which the German dye firms have invested in scientific research, has been the best paying investment which the world has ever seen.

It is true that the synthetic dye industry had, from its inception, the highly developed and rapidly progressing science of organic chemistry as its foundation. that is, the industry was not forced to explore a wholly new domain of science in order to ascertain fundamental principles and accumulate the data needed for its development. For the greater part of this material it could rely upon the results of the research carried out in the laboratories of the universities of the world.

In the case of the ceramic industries the situation has been somewhat different. The chemistry of the compounds of sili-

con, particularly the silicates, has not by any means reached the stage of development attained by the chemistry of the compounds of carbon, and in fact nearly all that we know concerning the chemistry and physics of high temperatures, which play such a dominant rôle in all ceramic industries, represents an acquisition of comparatively recent date. It is doubtless for these reasons that ceramics, as a branch, or as a potential branch, of applied science, received no recognition in the universities of the country until within the last quarter of a century. With the recent development of methods of producing, controlling and measuring high temperatures in the laboratory, however, has come the possibility of creating a new domain of science, the chemistry and physics of high temperatures. It is this new domain which will prove of fundamental importance to the ceramic industries, and the rapid expansion of our knowledge in this field should be encouraged and promoted in every way possible.

The committee believes that the industries concerned ought not, and in their best interests cannot, leave this work to the unaided efforts of university, governmental and institutional laboratories.

Fundamental research in this field is expensive, difficult and slow. New methods, new apparatus and new materials frequently have to be invented and created before the actual attack on the problem itself can be begun. The problems presenting themselves for solution are almost innumerable and many more workers especially trained for research in this field must be produced.

In the endeavor to enlist the active coöperation of the ceramic industries in furthering research upon fundamental ceramic problems in university, governmental and institutional laboratories of the country, the committee is submitting for consideration by the indisturies a plan for the establishment of Research Fellowships in Ceramics, each fellowship to be supported by one or more producers or users of a ceramic product.

In submitting this proposal, it seems desirable, in the interests of clearness, to explain somewhat more fully the distinction which the committee makes between "works problems" and "fundamental scientific problems." This can perhaps best be accomplished with the aid of one or two examples.

Typical examples of works problems are: The discovery of remedies (a) for the appearance of "white wash" on the ware in a waste heat drier and for the pitting and corrosion of the framework and cars of the drier; (b) for the formation of "kiln white" on the ware, or the production of "off color"; (c) for "blistering," "spitting out," "shivering" and "crazing" of glazed ware; and (d) deterioration of burned clay products under certain conditions. With the discovery of a successful remedy for the trouble the "works problem" is solved, regardless of whether the real cause of the trouble is known or the method if action of the successful remedy understood.

The source of some of the difficulties listed above has in many cases been ascribed to the presence of sulphur in the raw materials, the water, or the fuel employed, and the "disease" has often been cured by the avoidance of materials containing more than a minimum (determined by experience) percentage of sulphur. The chemistry of what takes place and how the reactions and equilibria depend upon the temperature and the partial pressures of the SO_2 and SO_3 in the gases of the kiln are, however, but little understood and the possibilities, which, in a given case, may exist of avoiding the necessity of employing a more expensive low sulphur material have not been investigated. Such problems represent the scientific aspects of the larger problem of the general influence of the presence of sulphur in the manufacturing system.

Other problems of this type are met in the manufacture of optical glass, the determinations, for each variety of glass, of the maximum temperature which must be attained in the melting process, the temperature at which stirring must be begun, the rate and amplitude at which the stirrer should be driven, and the temperature at which the stirring operation should be completed. Associated with this "works problem" is the fundamental scientific problem of the measurement of the viscosity of molten glass and the determination of the laws which govern the dependence of this physical property upon temperature and composition. In the same way the relation between composition and temperature, on the one hand, and viscosity, surface tension, gas content and vapor pressure of the molten glass on the other is a fundamental scientific problem intimately associated with the works problems connected with the process of fining.

To cite one more example, the chemistry of the rate and equilibrium of the reaction between aluminium silicate(or, more accurately, the aluminium silicates) and water, is a fundamental scientific problem at the root of works problems arising in the burning of clay wares (especially during the "water smoking" operation), in the rate of disintegration of the burned ware if afterwards subjected to high temperature and humidity, and in one of the common processes employed in measuring rate of vitrification.

Most "works problems" have behind them unsolved scientific problems. When the scientific problems have been solved there usually still remains a "works problem" for it is seldom indeed that the data of the laboratory can be immediately transferred to the works without further experimentation. The "works problem" which remains after the scientific questions at the root of it have been solved, however, often presents quite a different aspect from that which it presented at first.

IDENTIFICATION OF FUR.

We are all familiar with the existing practice of clipping, plucking, dyeing, and otherwise changing the appearance of lower class fuds to make them appear and sell for the more desirable varieties. The furs of animals whose habitat is in the warmer countries is not so durable, does not form as good leather, and is less supple than the furs from the animals living in colder climates, so that for some time there has been a desire for methods by which furs could be identified, even after going through elaborate processes.

Dr. L. A. Hausman of Cornell University gives a popular account of his researches in the SCIENTIFIC AMERICAN MONTHLY, Vol. 1, No. 1, January, 1920. By the use of the microscope and micro-chemical methods Dr. Hausman has found that there are characteristics of most mammalian hair which can be used as a key to identification. The characteristics of most importance are the scales of the cuticle, considering their shape and arrangement on the hair; the diameter of the hair and of the medulla; and the disposition of the pigment granules. A variety of methods is required to emphasize these characteristics. Staining methods, treatment with various reagents, extraction with alcohol and ether to remove interfering natural oils and other technique has been developed by Dr. Hausman.

It may be of interest to note the relative durability of the different types of commercial furs and since experience has shown that the fur of the sea otter is the most durable, that is taken as 100 in the following scale: beaver, 90; bear, 94; chinchilla, 15; ermine, 25; fox, natural, 40; fox, dyed, 20-25; goat, 15; hare, 05; kolinsky, 25; leopard, 75; lynx, 25; marten (skunk), 70; mink, natural, 70; mink, dyed, 35; mole, 07; muskrat, 45; nutria (coypurat), plucked, 25; otter, sea, 100; otter, inland, 100; oppossum, 37; rabbit, 05; raccoon, natural, 65; raccoon, dyed, 50; sable, 60; seal, hair, 80; seal, fur, 80; squirrel, gray, 20-25; wolf, 50; wolverine, 100.

The examination for identity is usually made upon the under or fur hair, and not upon the outer protective hair of the skin. It is interesting to note the effect of dyeing upon the wearing qualities of the various furs. This work makes it possible to take another step toward informing the purchaser as to the real character of the merchandise in which he is invited to invest.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

AN IMPROVED WORM GEAR.

In a description of a worm gear developed by a British concern, it is stated that in a certified test made at the National Physical Laboratory, Teddington, England, an efficiency of over 97 per cent was secured.

The illustrations (Fig. 1) show the details of the character and area of contact in the new F. J. gears. The view on the left shows the worm in such a position that the drive is taken by the three threads, *A*, *B*, and *C*, while that on the right shows the worm in a different position, having been rotated through an angle of 45 degrees, with the result that the two threads *A* and *B* are in simultaneous contact with the worm wheel. The area in dotted outline across the teeth of the worm marks the zone of contact between the gears when the worm is rotated in the direction indicated in the end view. The intersections of the worm threads and the zone give the

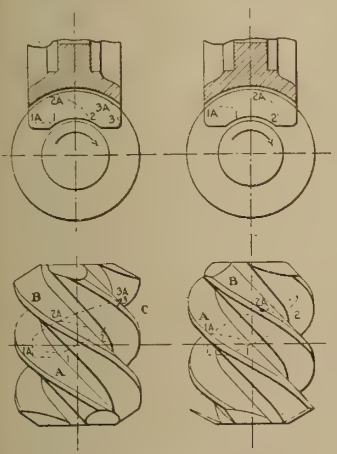


FIG. 1. ZONE OF CONTACT BETWEEN THE F. J. WORM AND WHEEL

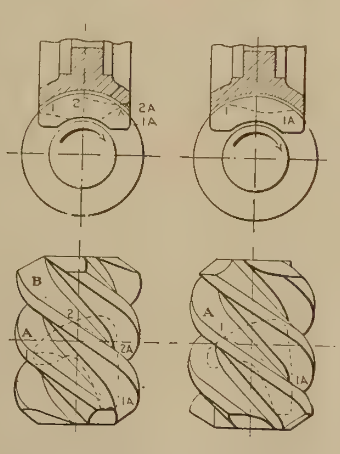


FIG. 2. ZONE OF CONTACT BETWEEN THE ORDINARY WORM AND WHEEL

lines of contact between the worm and wheel teeth, and at no point outside this zone is there any contact between worm and wheel. It is this contour of the zone of contact that was arrived at by the mathematical calculation previously referred to, and which was submitted to Faraday House.

In the left-hand view, the actual contact between the worm thread *A* and the wheel is marked by the dotted line 1-1*A*, that between the worm thread *B* and the wheel by the line 2-2*A*, and on the worm thread *C* by the line 3-3*A*. In the right-hand view this worm has been rotated through an angle of 45 deg., the new line of contact being again shown dotted, only in this case the worm thread *C* has passed beyond the zone of contact and has thus ceased to contact with the worm wheel.

The illustrations (Fig. 2) show the one of contact for a four-threaded worm of the ordinary shape in which the teeth of the worm are straight-sided in section; that is to say, in the form of a rack. As the linear section of this type of worm corresponds to a straight-sided rack, and as the straight-sided rack forms the basis of the involute spur gear this shape of worm is generally known as the involute worm. As before, the zone of contact is shown in dotted line, but in this instance two teeth only are in contact in the left-hand view—*A* and *B*—giving lines of contact 1-1*A* and 2-2*A*, while in the right-hand view the tooth *A* carries the entire load along the line of contact 1-1*A*. The unsymmetrical contour of the zone of contact will be observed. More noticeable still is the difference between the irregular lines of contact shown on the end views of the involute worm as compared with the symmetrical lines of the F.J.

It must be understood that in both cases whenever the worm is revolved through an angle of 90 deg., the line of contact 1-1*A* will sweep across the zone of contact until it takes up the position marked 2-2*A*, because when a four-threaded worm is moved a quarter of a revolution (or 90 deg.), the thread *A* will naturally take up the position of the thread *B*. In the F.J. system it will be seen that the point 1 at the root of the worm (end view) falls into the position 2 after a quarter of a revolution; that is to say, the actual contact travels *in the same direction* as the worm through a distance of approximately 50 to 60 deg., hence about two-thirds of the motion is transmitted by a rolling action and only one-third by sliding. This means that a rolling action is introduced between the teeth of the gears, thereby reducing the ordinary rubbing velocity to a minimum. Thus the gear teeth, instead of rubbing against each other at, say, 1,000 ft. per min., really only rub at the reduced speed of about 350 ft. per min., due to the rolling action of the F.J. tooth contact.

This is not so on the involute worm-gear system. In the left-hand view in Fig 1 the point of contact 1*A* actually moves *in the opposite direction* to the rotation of the worm to the point 2*A*, thereby giving the rubbing velocity even more than its full theoretical value, while rolling action, at the ends *A* of the lines of contact, is absolutely non-existent.

A peculiarly inefficient characteristic of the involute system is that the extremities of the lines of contact (see plan view of worm) travel from positions 1 and 1*A* *toward each other* until they meet, and vanish just beyond the points 2, 2*A*, as shown in the left-hand plan view (Fig. 2).

The plan view of the F.J. system (Fig. 1) shows the point *A* always moving from left to right, in the same direction as the rotation of the worm, while the left-hand plan view of the "involute" system shows the point *A* moving very slightly from right to left, actually against the rotation of the worm. The high rubbing velocity which occurs on the point *AA*, together with the converging lines of contact which induce a concentrated load, all tend to produce the worst possible conditions on the leaving side of the worm wheel. This explains the well-known fact that when a worm gear of the "involute" type is overloaded, "pitting" first takes place on this side of the wheel, and on this side only, while those portions of the teeth on the entering side of the wheel remain unmarked.—*The Automobile Engineer*, December, 1919, p. 449.

MAKING DIAMOND WIRE-DRAWING DIES.

Diamond dies are extensively used for drawing small wire made of all kinds of metals and for sizes from 0.08 in. down they are used practically exclusively. Because of this the following data as to the manufacture of such dies by the Vianney Wire Die Works at Trefoux, France, become of interest.

For the manufacture of dies diamonds are used which are of a grade unsuitable for use in jewelry.

The firm standardized the size of diamonds from which dies of different diameters are made, the diamonds themselves ranging from one carat to sizes as large as twenty carats.

As is generally known, the diamond is so hard that it can be cut only with another diamond or diamond dust. The first step is the flattening of a rough stone, which is done with laps charged with diamond dust made by pulverizing small-sized diamonds or chips from larger stones and then grading

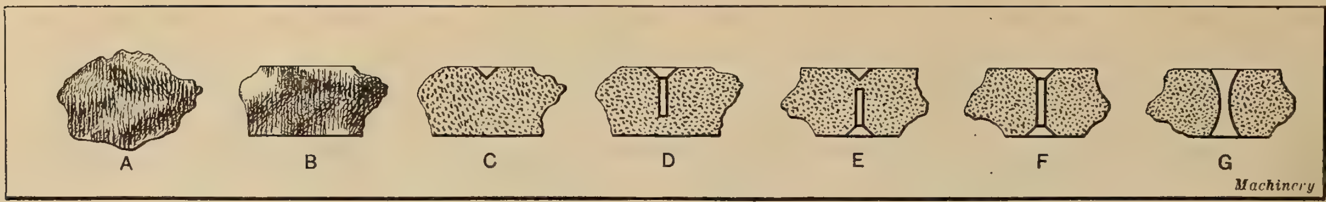


FIG. 3. ROUGH DIAMOND *A* AND CROSS-SECTIONAL VIEWS SHOWING SUCCESSIVE STEPS IN THE PROCESS OF MAKING WIRE-DRAWING DIES

the dust by sifting it through sieves with various numbers of meshes per square inch. This is succeeded by several operations, comprising the cutting of the die opening. The first step is to chuck the diamond on the faceplate of a special drilling machine and cut a conical-shaped opening, as indicated at *C*, Fig. 3. This opening is made by means of a diamond chip held by hand between the points of a pair of long-nosed pliers. After the conical hole has been cut, the drilling operation is started by means of a tool carried in the spindle of the machine, which is so designed that the table rotates and also has a vertical reciprocating motion imparted to it.

After the hole has been drilled about three-quarters of the way through the diamond, as indicated at *D*, the work is removed from the machine and turned over, after which it is reset and the conical opening is cut in the opposite side of the diamond, as indicated at *E*. Of course, this second conical opening has to be located exactly opposite the hole which has been drilled in the work. The next step is to drill from the bottom of this conical opening to make a connection with the hole entering the stone from the opposite side, *F*. It is very important to have the inside of the die absolutely smooth in order to prevent forming seams in the work and also to have the bell mouth of the die formed in such a way that the metal will pass into the die without undue frictional resistance. This is done by giving the die the shape shown at *G*. The inlet to the throat of the die is made slightly larger than the outlet at the back, which requires a great amount of dexterity to do. The dies are set in brass mounts.

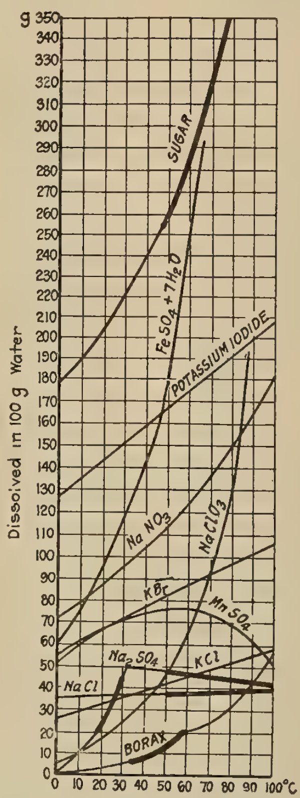


FIG. 4. SOLUBILITY CURVES OF VARIOUS SALTS

The feature of diamond dies which makes them more economical in use than steel, cast iron or other comparatively inexpensive materials, is that they give a far greater amount of service before the tool is worn out, because of the extreme hardness of the diamond. The resistance against wear is also the means of maintaining greater uniformity in the diameter of the wire that is drawn through the die.

The time comes, however, when the die becomes too large to produce wire that comes within the specified limit of tolerance. When this point has been reached the dies is recut for a larger size, which is done by the use of a steel lapping tool charged with diamond dust. In connection with this operation the bell-mouthed opening must again be carefully finished to bring it tangent to the new throat which has been cut in the die and the inner surface must once more be carefully polished. The original article illustrates the special type of lathe used for refinishing diamond dies.—*Edward K. Hammond in Machinery*, Nov. 1919, pp. 264-266.

SALT PRECIPITATION BY REFRIGERATION

In the chemical industry many salts have to be precipitated out of mixed solutions by means of crystallization. This is done by cooling the concentrated brines to the point where their ability to maintain the salts in solution is reduced.

Fig. 4 gives the solution curves of several salts in water, indicating how much of the salt at various temperatures may be contained in 100 grams of water (saturated solutions). As shown by these curves, the solubilities of various salts are unlike to an extraordinary degree and each salt permits to secure a greater or lesser precipitation out of a brine at a given temperature.

Thus, for example, in the case of Chilean saltpeter ($NaNO_3$) cooled from 90 to 20 deg. cent. (194 to 68 deg. fahr.), out of 165 grams held in solution at 90 deg. cent. so much is precipitated out that only 88 grams remain in solution.

The curves show that many brines can maintain quite considerable amounts of salt in solution even at 20 deg. cent. (68 deg. fahr.) and that substantial amounts of crystals are precipitated only when the brine is cooled to a much lower temperature.

Because of this, provision has to be made for certain salts to cool the brine to quite a low temperature and Fig. 5, for example, shows an installation built to precipitate out of its solution potassium chloride. In that case 3,000 grams of brine at 20 deg. cent. when cooled to — 10 deg. cent. (14 deg. fahr.) will precipitate out in crystal form 200 grams of potassium chloride.

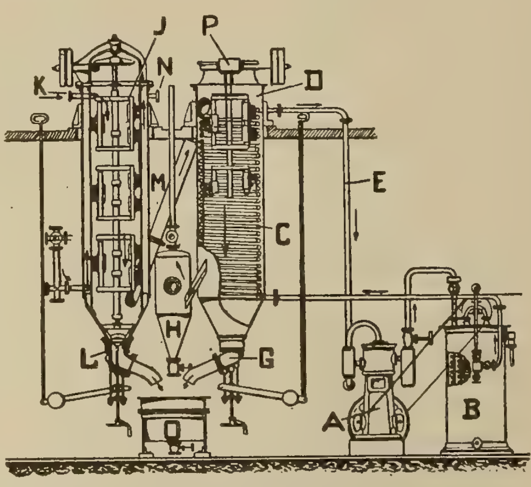


FIG. 5. EMIL PASSBURG INSTALLATION FOR PRECIPITATION OF SALTS OUT OF SOLUTIONS BY REFRIGERATION

The cooling is effected in two stages: by means of a water cooler to + 20 deg. cent. (68 deg. fahr.), and then in an ammonia refrigerating machine to — 10 deg. cent. (14 deg. fahr.).

The ammonia compressor *A* compresses the ammonia and forces it into a coil condenser *B*, in which ammonia under a pressure of 8 atmos. is liquefied by cooling water having a temperature of 15 deg. cent. (59 deg. fahr.). The liquid ammonia, the flow of which is controlled by a special valve, is then again vaporized in the coils *C* of the crystallization cooler *D*, the ammonia then going back to the compressor by means of pipe *E*.

The precipitation of the crystals is produced by cooling brine in cooler *B*, the salt settling mainly

on the cooling coils C. It is then swept off of them by special adjustable brushes, which also help to maintain the efficiency of the cooling action of the coil C. The crystals precipitated in this way sink through the brine and collect in the cone-shaped bottom of the cooler whence they are from time to time discharged into the straining tank O through a quick-acting valve G. It is necessary to have the valve of a quick-acting type in order to have the liquid pressure discharge the crystals containing brine without letting out too much liquid itself. The straining tank O has on top a fine screen on which the brine falls. The thin liquid passes through and is strained off while the crystals stick on top of the screen and are collected therefrom from time to time.

In the installation described approximately 6,000 calories (say, 24,000 B.t.u.) would have to be taken up from the refrigerating plant per hour. In order to reduce the consumption of cold the installation is so arranged that the brine which leaves the crystallizing cooler D at H is conducted to the jacket of a second crystallizing cooler J and on the way pre-cools the fresh brine which enters at K with the temperature of 20 deg. cent. (68 deg. fahr.).

Brine entering with the temperature of — 10 deg. cent. (14 deg. fahr.) takes up heat to the extent of leaving the cooler J with the temperature of 5 deg. cent. (41 deg. fahr.), whereas the fresh brine which enters with the temperature at 20 deg. cent. (68 deg. fahr.) leaves with the temperature of 5 deg. cent. (41 deg. fahr.). The salt which is crystallized out in the meantime is swept away by brushes in the same manner as in the first cooler and precipitates out through the quick-acting valve L into the same straining tank O. In this manner the consumption of cold is reduced to about one-half.

In computing the consumption of heat in refrigerating installations of this type it is necessary to bear in mind that in addition to the heat which is necessary to cool the brine itself, quite considerable amounts of heat have to be taken care of as heat is given up in the process of precipitation by crystallization at the instant when the dissolved salt passes into the form of crystals, the amount of heat thus given up being the same as that which was previously consumed in order to dissolve the salt. In the case of cooking salt about 20 calories per kilogram (35 B.t.u. per lb.) were consumed, for potassium chloride ($KClO_3$) about 81.5 calories per kilogram (147 B.t.u. per lb.) and so on.—*Berthold Block* in *Zeitschrift für die Gesamte Kälte-Industrie*, August, 1919, pp. 57-59.

PUDDLED IRON PRACTICE.

Notwithstanding the impression prevailing among laymen today, steel is a comparatively recent product. Its general use, that is, aside from using tools, dates from the introduction of the Bessemer process in the middle of the last century. Until then the world knew iron in the form of either cast iron or wrought iron and when Kipling put into the mouth of one of his God heroes the line

"What iron called iron is master of them all?"

he meant just what he said, iron and not steel.

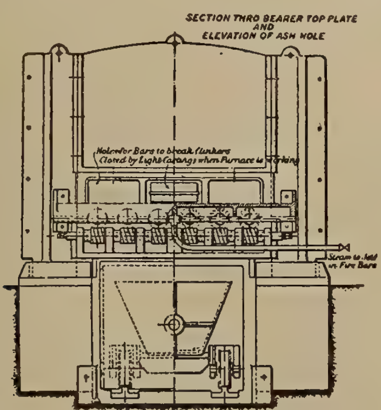


FIG. 6. END ELEVATION OF FURNACE ARRANGED FOR EASY REMOVAL OF ASHES

Bessemer first and open-hearth steel next proved to be in many respects superior to iron to such an extent that they displaced it practically forever.

Steel is better wearing than iron as regards mechanical stresses and after a while proved to be even cheaper. Because of this the production of puddled iron, which took on a new life with the invention of the Hall process about a score of years before the invention of the Bessemer converter, lagged behind both commercially and technically. Scarcely any new furnaces for the production of puddled iron were set up previous to the war in the last fifty years, and some of those which were in existence have either shut down or converted to steel manufacture.

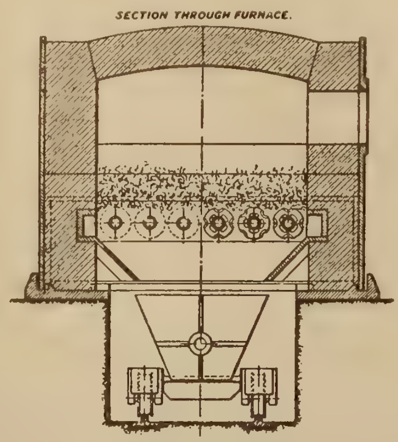


FIG. 7. SECTION THROUGH FURNACE SHOWING ARRANGEMENT OF GRATES

Nevertheless puddled iron has certain advantages over steel in its better ability to resist rust and heat.

This brought about an interesting revival of the puddled iron industry in the last few years.

Hall's process lies at the root of present and future puddling processes and is not likely to be superseded. It is conceivable that further attempts may be made to produce wrought iron directly from poorly silicious ores or by the decarburization of cheaply produced mild steel, but there are fundamental difficulties in the way of success affecting the character of the crystalline structure and the related welding and fibering properties of the resulting product.

There are three factors in puddling that affect the entire situation. These factors are:

1. The puddling furnace as we know it is one of the most wasteful of metallurgical furnaces using more fuel per ton of product than any other continuous process.

2. The labor cost per ton is abnormally high as is also the cost of furnace upkeep.

3. The rolling, shingling and material handling and transport plants are usually crude and excessively wasteful in power cost per ton of product.

The writer vigorously criticizes the design of coal-fired puddling furnaces, claiming that the radiation losses in such a furnace and its waste heat boiler amount to at least 20 per cent of the heat energy of the coal burned, or equivalent to, say, 560 or 784 lb. per ton of puddled-iron heat, whereas in the steel furnace the radiation losses do not exceed 224 lb. per ton of steel cast.

The radiation losses in a puddling furnace per unit of metal charged average from 10 to 15 times as much as in the open-hearth steel furnace, and so on.

On the whole, the author comes to the conclusion that the small furnace used in puddling is a real obstacle to fuel economy as its relatively large hearth causes the excessive radiation areas.

The construction and proportions of the modern puddling furnace are not likely to be substantially altered or improved, but it is possible to improve the grate and firebox and to provide efficient means for burning the poorer coals—in partic-

ular, to reduce the amount of unburned fuel that goes into the ashpit. Figs. 6 and 7 show sections of a furnace arrangement designed by the author.

The grate consists of a series of tubular bars perforated for air ejection, over which a number of specially shaped chilled cast-iron disks are threaded. These form a kind of roller grooved longitudinally, so that when it is rotated it causes clinkers to crack and burned ashes accumulated in the troughs between the roller bars to roll into the ashpit.

The air required for combustion is forced through the tubes by steam jets and passes out through the perforations into the fuel bed and ashpit which is closed by the front plate of the ash-removal car. The air ducts between the grate disks are nozzle-shaped and the grates can be cleaned without opening the doors. Large clinkers can be removed through the large holes provided above the grate in the firebox plate.

The application of gas firing to small puddling furnaces has also been suggested and a furnace was built with a small producer at the firing end.

The process of puddling covers three stages, namely, the melting stage, occupying 30 to 40 min. depending on the class of pig iron used and the efficiency of the fuel; the boiling stage occupying 30 min.; and the drying and balling, followed by fettling and charging periods, occupying about 40 min.

It appears further than the melting period demands, under the present conditions, from a little over 5,000 lb. to close to 6,000 lb. of coal per ton of metal melted and is the most wasteful stage of the puddling process.

Cupola melting which would be more economical as far as fuel consumption goes is not suitable as it yields a higher-carbon metal and very little reduction of the remaining metalloids, and because of this the boiling period in the puddling furnace is lengthened.

The author proposes a special method of procedure based on manipulation of the slags with a view to producing a low-sulphur metal from the cupola described in the original article.

The characteristic feature of the new process is the addition of manganese at a certain stage which causes a delay in the elimination of the carbon, while it accelerates the elimination of silicon and phosphorus. A liquid slag resulted and the metal poured flows easily and is well deoxidized.

The author also proposes the design of a plant consisting of an open-hearth tilting or fixed basin-lined furnace, the waste heat from which is used in attached efficient boilers fitted with auxiliary fuel supply apparatus, this latter having the purpose of increasing the steam requirements during the charging and tapping stages. From the open-hearth roughing furnace the metal is ladled to mechanical puddling furnaces fired with pulverized coal and having waste-heat boilers attached to them.

Each of the units composing the proposed plant are at work. The open hearth furnace is regularly melting iron on a pulverized coal consumption of 448 to 560 lb. per ton of iron melted. Puddling furnaces similarly fired are operating on a consumption of 1,300 to 1,600 lb. per ton of puddled bar, when dealing with cold pig iron. When puddling molten charged material the coal burned should not exceed 800 to 1,000 lb. per ton of product, six furnaces doing the work of the present ten.

If the roll trains and shingling machines or squeezers be operated by electrical power, and they can be, it is conceivable, that, given cheap electrical energy, such a combination of the duplex system with mechanical puddling furnaces and with electrical rolling and shingling equipment should furnish the most economical puddling plant possible.—Paper by *J. E. Fletcher* before the Staffordshire Iron and Steel Institute read Nov. 22, 1919, abstracted through *The Iron Trade Review*, Jan. 8, 1920, pp. 152-156.

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

A SUBSTITUTE FOR PLATINUM CRUCIBLES IN ELECTRIC ANALYSIS.

RECENT experiments in the Chemical Institute at the University of Bonn have shown that the platinum vessels, customarily employed as cathodes can be advantageously replaced by glass vessels whose inner surface is silvered. In order to obtain a layer of silver which will adhere closely to the vessel the inside of the latter must be treated with a sand blast, so that the surface resembles that of ground glass. It is less advisable to produce this effect by means of the vapors of acids, since this method does not usually produce so uniform an effect. Before the first application of the silver the vessels must be thoroughly cleansed with chromic acid then with soda lye and finally with nitric acid.

The silver solution employed consists of an ammoniacal solution of silver nitrate which has been reduced by the addition of 2 ccm. of a 40 per cent formalin solution. At a temperature of not more than 30° C. there is obtained in from three to four minutes a silver precipitate of from 0.03 to 0.05 grams, which has a uniform mat surface, and which is dark blue in color by transmitted light. The vessel is then dried and provided with a strip of sheet platinum, 2 mm. in breadth, one end of which must touch the silver coating, while the other is bent so as to hang over the edge of the vessel outside; this end is provided with a screw clamp. Other experiments, having as their object the replacing of platinum anodes by carbon anodes, have thus far yielded poor results, but will be continued with Acheson carbon. The glass cathodes just described gave excellent results in tests made with copper, cadmium, zinc, nickel, cobalt, and mercury, showing that they could readily be used as substitutes for the platinum vessels whose cost is now almost prohibitive.—*H. Gewecke* in the *Chemiker Zeitung* (Berlin).

A SUPER-POWER TRANSMISSION SYSTEM.

IN the territory between Boston and Washington and inland from the coast averaging 100 miles, which territory may be described as the finishing shop of American industry, there is an installed machine capacity of 10,000,000 horse-power. At the same time the load factor of this great regional demand for power is not more than 15 per cent. This means that for every 15 h.p. required 100 h.p. is installed. Today, due to improper form of power generation and distribution, for every ton of coal burned another is wasted—literally thrown away.

It is quite amazing to learn that there is shipped into the eastern territory 37,000 tons of coal daily for public utility central stations. The total coal tonnage used by all the electric power plants engaged in public service is only 95,000 tons daily, and thus in only a part of the zone under discussion, representing less than 5 per cent of the total area of the United States, there is required 40 per cent of the total amount of coal so used. Again, to ship this amount of coal

into this district requires over 800 cars in and out every day. This would represent a solid train of coal cars seven miles long.

If it is further considered that our coal fields are being rapidly exhausted and that our merchant marine is soon to carry the products of our industrialism the world over, it is clear that we must have economical power, *i. e.*, cheap and reliable power. Especially is it true of the territory under discussion where the power must in a large measure be furnished with fuel as a base. Economical power is the sole remaining means to prevent this finishing shop of American industry from being converted into the playground of American tourists.

The solution lies in the construction of high powered, high economy tidewater steam and hydroelectric stations and steam stations erected at the mouth of mines, within the territory named, all interconnected with a super-power transmission system, using also the large plants now in existence in the larger cities, such as Boston, Providence, New York, Philadelphia and Baltimore. The present companies would maintain their present entities, carrying all their present franchise rights; they would become merely distributers of power. The districts in which they operate would receive power in bulk from the super-power system at the points of their present stations and substations to be erected.

This plan has the hearty endorsement of the engineering press and of such societies as the Boston branch of the American Institute of Electrical Engineers, the National Electrical Light Association and of the Engineering Consul. Furthermore, it has the approval of Dr. George Otis Smith, Director of the Geological Survey, and of Secretary Lane, who is asking Congress to provide sufficient funds to the Department of the Interior by which an investigation can be made to allocate the losses now sustained and to be inclusive of recommendations covering a power transmission and distribution system by which they may be saved.

It is admitted that the financing of such an enterprise will involve the expenditure of a very large sum of money, which, however points to the truth that we are not only upon the eve but in the realm of far larger things than have concerned us in the past. Yesterday we were willing to spend a million dollars in construction to save one hundred thousand a year. Today we are ready to spend a billion to save a hundred million a year. "We have spent billions for destruction for preservation, now let us spend billions for construction for conservation."

It is estimated that the following advantages would result from such a super-power transmission system: (1) The power required in the industries of the zone under discussion as well as for its aggregate of 7,000,000 h.p. steam locomotives would offer unexampled opportunity in the application of diversity factor, that is power delivered from the same source to different points at different times; such a system would have the maximum load factor possible and the lowest coal consumption, resulting in an annual saving of $3,000,000 to the nation. Moreover, if the curves of recent progress are continued the electric power used in New England will increase four fold and the economies of the future should greatly exceed the figure given above. (2) It would release the railroads from the hauling of the 50 per cent of the coal now transported. This is very important as the limit to industrial expansion is likely to be the transportation facilities. If industrial expansion is to continue the railroad facilities must be increased, and the way to increase them in congested regions is by electrification. This not only increases the traffic capacity of tracks and terminals but it reduces the coal required for railroad operation. A general electrification of industry will further reduce the coal to be transported, thereby releasing the equipment for industrial freight.

3. While the cost of power does not represent more than 5 per cent of manufacturing cost, yet electricity *is* the agent of highest efficiency in power application and the greatest agent to *facility*. This country is to produce more and more if it wishes to maintain its supremacy in world's trade. Even if the cost of the application of electricity were twice as much as steam, its contribution to the facility of production, in nearly every form, would far outweigh the additional cost. Especially is it true of New England which is a manufacturing community without raw materials or coal.

4. Such a system would provide continuity of power production—due to an established breakdown service between power centers, and would greatly do away with fuel crises, such as was faced by New England in the winter of 1917-18.—*W. S. Murray* in the *Journal of the American Institute of Electrical Engineers*, January, 1920. Address delivered before the Connecticut Chamber of Commerce.

RADIO-TELEGRAPHY BY INVISIBLE INFRA-RED RADIATION.

J. Herbert Stevens and A. Larigaldie have perfected a detector apparatus, particulars of which have recently been communicated to the Paris Academy of Sciences. With their device they have been able to obtain records of infra-red radiations over distances of more than 20 km., the best results being obtained with a thermocouple.

In the tests as carried out the source of emission was an arc or electric lamp projector, the luminous flux of which was absorbed by a filter screen, a black glass coated with manganese dioxide or gelatine. These screens absorb 50 per cent of the total energy, but do not allow any rays which may affect the eye to pass.

The receiver is a parabolic mirror arranged to trap the maximum of radiant energy; the thermophile being placed at the focus of this mirror.

A metal plate 1/100 mm. thick is autogenously welded to the point of a crystal of high thermo-electric power. The thickness of the plate and the diameter of the point of contact were kept as low as possible so as to form a whole of very low thermal capacity. The best results were obtained with a platinum plate and a crystal of tellurium tempered and welded in the direction of crystallization. The junction is enclosed in a glass bulb having a fluorine window.

The thermocouple is mounted at the terminals of a lamp amplifier, the current being broken by a ticker of musical frequency. A potentiometer is connected up in the circuit in order to obviate all eddy currents due to the surrounding conditions which might cause a difference of constant temperature between the two junctions.

The diminuntion in the radiant energy captured at the receiver is generally proportional to the distance covered from the transmitter, but regard must be had to the absorptive power of the atmosphere, which is sometimes low and sometimes considerable according to the proportions of water-vapor, fog, dust, and CO_2.

Where the thermophile is not used in telegraphy but in pyrometry, in tele-mechanics, or for revealing the presence of bodies whose temperature differs from that of the surroundings (*e. g.*, icebergs at sea), its current is passed into a fairly sensitive galvonometer to give a deflection of 3 to 4 mm. per micro-ampere (2 to 3 ohm coil).

For ships the authors have designed a special double pivot galvanometer of the same sensitivity as the previous one, which is capable of working in any position and is unaffected by pitching or rolling.

The following tests made are worthy of mention:

(1) In September, 1918, signals were exchanged between two stations 14 km. apart. The transmitting station was provided with an arc projector of 1.50 m.

(2) In May of this year signalling experiments were made between two stations 7,500 meters apart. At the transmitting station there was a 0.40 m. mirror and an 800 watt nitrogen-filled electric lamp; while at the receiving station a gilt mirror of 0.24 m. was used. (Genie Civil, Aug. 2, 1919.)

AUDIBLE ELECTRIC SIGNALS IN INDUSTRIAL PLANTS, AND ACOUSTICAL ENGINEERING.

Under the impetus of the pressure for greater efficiency and increased production the modern plant finds it a paying proposition to install a system of loud acoustic signals. Such electric signals are usually similar in construction to the familiar electric "horn" used on automobiles. It consists of a diaphragm with an anvil at its center. A toothed wheel driven by a small electric motor strikes the anvil many times a second and causes it to vibrate vigorously. These vibrations produce the well known warning tone, which carries over a considerable distance. The device is provided with a projector or horn the shape of which depends on whether it is desired to scatter the sound, to intensify it in horizontal direction, or to deflect it downward. Such motor driven signals are now made much more powerful than automobile horns, and are wound for 110 or 220 volts, direct or alternating current, so that they can be connected to a lighting or power circuit, and do not require a separate low-voltage battery. By means of these signals calls could be given only imperfectly by pushing a button, and for this reason a special code calling instrument has been developed, which closes electric contacts automatically, after having been set for a desired combination; it can also actuate a bell, a buzzer or an electric lamp.

The uses of such electric signals are many, and their prime advantage in each and every large plant is the elimination of the waste of much time usually lost by the officials, experts and important employees in trying to locate each other. With loud signals installed throughout the plant it becomes possible to locate any of a considerable number if men instantly, using a simple code call for each. In noisy places—steel mills, textile mills and printing establishments—they are used as extensions to telephone bells. They can also be used as warning signals on cranes, local signals at various furnaces and rolling mills. Their importance in increasing the efficiency and safety in shipyards and coal mines should not be underestimated. They are equally applicable to construction jobs where, in the absence of electric power, they could be operated from 6-volt storage batteries. A large number of such horns have been recently installed on various U. S. naval vessels as fire alarm signals, for general alarms, as hoist signals and also for code calls throughout the ship. At large public gatherings, conventions, festivals, etc., such a system of signals could reach any one of the participants which is wanted either by the executive committee or for delivery of important mail, etc. A new application of audible signals well worth looking into is the hold-up alarms for banks. With a masked man pointing a revolver at him, the teller could press a push-button with his foot, which would cause an alarm to sound at the next street corner, or somewhere in the building where certain men have been trained and armed for such an emergency.

In industrial plants and other places in which acoustic signals will be gradually installed, the engineer will soon be confronted with various acoustical problems: the indistinct noise known as reverberation, sound interference, consonance, echoes and zones of silence. Fortunately, physicists and architects have done some splendid ground work in this direction. Prominent among them is Prof. Wallace C. Sabine of Harvard Univresity, who made numerous tests of the relative absorbing power of different substances, using organ pipes as the source of sound. Other investigations on transmission, reflection and absorption of sound by different materials were made by F. R. Watson, by H. D. Taylor and by C. S. McGinnis.

Prof. A. L. Foley of Indiana University opened a field of many possibilities in experimental acoustics by perfecting the method for directly photographing sound waves. These photographic researches promise a method for an experimental study of sound waves under conditions which are too complex for theoretical computations. Dr. Sabine has applied this method to the solution of acoustic problems in some theaters. It is quite possible that this method may prove of utility in the solution of similar acoustic problems in industrial plants. Photographs taken on models of complicatel shipyards, coal mines or a mill full of machinery may explain some observed abnormal conditions, such as zones of silence and a departure of the sound intensity from the simple law of inverse squares.

If acoustics is to become a branch of applied science simple and robust instruments must be developed for measuring the physical quantities involved, particularly the sound intensity. An electric horn may be guaranteed to produce a sound intensity of so many "Carusos" per square centimenter, at a distance of say one hundred meters from its diaphragm. The need of such instruments has already been felt in connection with fog signals. A simple indicator of sound intensity is the so-called Rayleigh disk, which has not been used much in practical acoustical measurements. An instrument of considerable accuracy and sensitiveness for measuring sound intensity at a point is the phonometer developed by Dr. A. G. Webster, of Clark University.

A sensitive telephone receiver may be used for measuring the sound intensity, as the current induced in its windings is proportional to the sound intensity. The induced currents are measured by a crystal rectifier and a dic. galvanometer, or by means of a very sensitive vacuum thermometer. Prof. Miller's phonodeik distorts the relative magnitudes of the harmonics and requires tedious corrections to reconstruct the actual sound wave.

It is evident that the question of selective sensitiveness of the human ear must also be considered, and the energy measured only within the audible range; the range of maximum sensitiveness of audibility lies between 700 and 3,000 vibrations per second. Systematic experiments will be needed on the sensitiveness of the human ear not only to sounds of different pitch, but to the same sounds accompanied by disturbing noises. Only a beginning has been made in this direction.

The diaphragm is the most essential part of an electric horn. A large number of investigators have worked on this problem in connection with the telephone, phonograph and other reproducing devices. The problem is further complicated by the fact that the diaphragm is seldom used alone but usually has a horn associated with it. This horn adds its natural frequencies due to the enclosed air and thus modifies the properties of the diaphragm itself. Besides, there are unavoidable little cavities where the diaphragm is built into a housing, and these cavities act as resonance chambers adding to the troublesome selective sensitiveness of the combination. A systematic study of these factors is still in its infancy and offers a big and fruitful field for the future investigator.—*V. Karapetoff* in the *Journal of the American Institute of Electrical Engineers*, January, 1920.

EFFECT ON EXPOSED WIRES OF THE ELECTRICAL CHARGES CARRIED BY RAIN-DROPS.

To investigate the causes of the electrical disturbances in air lines and the changes, often without apparent cause, in the pressure and current-intensity in electrical networks, and to see if they could be accounted for by the electrical charges carried by rain-drops, the authors carried out experiments with an insulated copper wire 100 meters in length. They have found that the charge on the insulated wire is sometimes of the same and sometimes of opposite sign to that of the charge carried by the rain. The potential of the wire frequently exceeded 1,000 volts, and it was not uncommon to obtain sparks of 2 or 3 mm. between an extremity of the wire and an earthed plate. The authors conclude that an insulated wire acts as an equalizer of potential, and that, therefore, the disturbances are caused by the earth's electrical field, rather than by the charges conveyed to the wire by rain. —*A. Baldit*, *Comptes Rendus*, Nov. 17, 1919. Abstracted through *The Technical Review*.

Progress in Mining and Metallurgy

Abstract of Papers to be Read at the February Meeting of the American Institute of Mining and Metallurgical Engineers, and Summaries of Important Articles in Current Periodicals

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

ELECTRIC FURNACES FOR NON-FERROUS METALS.

Electric furnaces are now in actual use for the melting of brass, aluminum, zinc and other metals. Attempts to utilize furnaces of the arc type for melting metals which readily oxidize and volatilize resulted in comparatively high metal losses. Recourse was therefore had to the induction furnace, but this type has been built for non-ferrous work only in units of small capacity, has a lower power factor, and is said to be comparatively costly in upkeep; the purely resistance furnace, on the other hand, has both a high power and load factor.

The heating element consists of a trough filled with a granular resister material, and although the furnace appears to be of large size in relation to output, metal losses are, it is claimed, reduced to a very low figure. On a six days' run on yellow brass scrap, the actual metal losses were 1.3 per cent., while during a period of six weeks the over-all metal losses were only 0.811 per cent. The resister troughs are said to have a four months' life, and the material with which they are filled a two weeks' life under normal operating conditions. Owing to the absence of intense local heating, the refractories are said to require renewal only at long intervals. Five of the furnaces are in use at one plant for melting an alloy which contains over 80 per cent zinc. They are made in sizes ranging from 40 kw. up to 1,000 kw., but the unit size more generally adopted is the 105-kw., round, hand-tilting type, which has a normal hearth capacity of 1,500 lb. and a melting rate of 600 lb. per hour.

Experience and commercial practice shows the current consumption to vary from 300 to 350 kw.-hr. per ton of yellow brass scrap melted. The larger furnaces, of from 500 to 1,000 kw., are of the rectangular nontilting or tapping type. The cold charge is introduced through motor-operated doors, and rabbling doors are conveniently placed. One of these furnaces, used for remelting aluminum pig, is supplied with 500 kw. and has a hearth capacity of 3 tons. The same furnace has a hearth capacity of 9 tons of brass, with a melting rate of 2 tons per hour when supplied with 600 kw. A 1,000-kw. furnace of this type is employed for melting zinc cathode, and has a capacity of 200 tons per day. Its operating sheets show that the percentage of metal dross averages 0.024 per cent. —Paper presented by *Verdon C. Cutts* at meeting of Institute of Metals held in Sheffield, England; published in *The Engineer* (London) of Oct. 10.

PULVERIZED COAL AND ITS FUTURE.

Remarkable strides have been made recently in the adoption of pulverized coal as a fuel for stationary boilers, and this development is now attracting considerable attention. Pulverized coal was burned in boiler furnaces, but with destructive results to the refractories, because the fuel, being in suspension in nearly a gaseous condition, was burned in furnaces designed for other methods of firing.

In the earlier days, the coal was not pulverized to the present standard degree of fineness and also it was not as carefully dried. Furthermore, it was introduced into the furnace at too high pressures, with a resulting blowpipe effect which created local zones of high velocity gases in the furnace, against the refractories.

It was not thoroughly understood that there was a certain relation necessary between the volume of the combustion chamber and the quantity of fuel fired per unit of time. The many continued attempts that were made developed the fact that the basic reasons for the destructive conditions in the furnace were contracted volume and excessive velocities of the gases of combustion passing through the furnace. It has been found that the maximum velocity that can be maintained without destruction is 7 ft. per sec. This, stated in terms of boiler horse-power developed, would equal approximately 2 cu. ft. of furnace volume per boiler horse-power developed, assuming that the combustion chamber was nearly in the form of a cube. The limiting feature would be the velocity of the gases through the smallest cross-sectional area and where the highest temperatures prevail. Absolute control of furnace temperatures prevents to a great extent refractory troubles and consequently reduces furnace maintenance.

ADVANTAGES OF PULVERIZED COAL AS A FUEL.

The principal reason for pulverizing coal is to make it burn more easily. Combustion is continuous. Pulverizing permits of a more complete mixture of the particles with the air, so that complete and practically perfect combustion is obtained with a low percentage of excess air. When coal is pulverized to the standard degree of fineness—that is, 95 per cent through the 100-mesh sieve and 85 per cent through the 200-mesh sieve—its surface exposure is increased between seven and eight hundred times and the number of particles in a cubic inch of puverized coal of this fineness is somewhere between 500,000,000 and a billion. The subdivision of the particles of combustible is so great that they exceed even that possible of attainment by the use of oil in the present oil burners, and therefore higher efficiencies are possible, due to the better mixing of the fuel with the air, than can be expected by burning fuel of any other kind, except, possibly, natural gas, or by using any other method of burning coal.

The furnace contents previously specified refer to the use of pulverized bituminous coal in stationary boilers. The same general rule holds good for all high volatile coals or coals in which at least 25 per cent of the total combustible is volatile matter. Where other fuels are concerned, such as anthracite or coke breeze or any other grades of low volatile fuels, the furnace must be designed to suit these fuels. Where low volatile coals are burned, it is necessary to locate the burners through which the fuel is introduced to the furnace at a point sufficiently close to the flow of the products of combustion on their way to the boiler, in order to assist the initial ignition of the fuel by a regenerative action in the furnace, and this action can only be obtained by the return flame approaching near the jets of fuel entering the furnace.

LOW-GRADE COALS CAN BE USED.

All grades of coal can be burned in pulverized form and all grades of commercial coal can be burned with high efficiency regardless of the percentage of ash. This method has opened up and made useful wide fields of low-grade coals hitherto not available due to their peculiar nature. Among these might be mentioned lignite coals, graphite anthracite coals of Rhode Island, and also various kinds of waste fuels from mining operations.

There is practically a complete elimination of standby losses

where pulverized coal is used. If the firing operation ceases the doors are closed. No air is allowed to pass through the furnace and the radiant heat of the furnace is absorbed by the boiler. There are no metallic parts exposed to the action of the heat and interfering with continuous operation in pulverized coal burning. There are no fuel beds or clinkers to interfere with the air supply. The arguments, therefore, in favor of pulverized coal method of firing appear very strong.

COST OF PREPARATION.

The adoption of this method of firing, however, for any particular installation, depends strictly on the cost of preparation. The cost of preparation varies with the quantity of fuel burned daily and it is a question of the profit in sight as to which equipment will show the greatest returns on the investment for any plant of a given capacity. In the table here shown, the first two items are nearly constant. The drier fuel will vary slightly, according to the price at which coal is received. The cost of labor diminishes as the quantity of coal increases. The power is assumed to cost ¾c. per k.w.-hr. The repairs at 7c. per net ton. The drier fuel is based on coal at $5 per net ton delivered with an average moisture content of 7 per cent, assuming that 6 per cent of moisture would be driven off per pound of coal in the drier. The furnace labor is assumed at 50c. per hour.

Cost of Pulverizing and Delivering the Pulverized Fuel to Boiler Furnaces

Daily Capacity, Tons	Cost of Labor, Cents,	Number Labor Hours	Repairs Cents	Drier Fuel, Cents	Power	Cost of Pulverizing Cents
20	30	12	7	6	13	56
30	30	18	7	6	13	56
40	25	22	7	6	13	51
80	20	32	7	6	13	46
120	18	42	7	6	13	44
160	17	48	7	6	13	43
240	13	62	7	6	13	39
320	11	72	7	6	13	37
400	10	83	7	6	13	36
480	9.5	94	7	6	13	13.5
640	8	104	7	6	13	34
800	6.75	108	7	6	13	32.75
960	6	114	7	6	13	32
1;120	5	116	7	6	13	31

No interest, depreciation, insurance or taxes have been included in the above total.

The cost of pulverizing should not be considered as an additional expense in the preparation of the coal in pulverized form, when comparing the total cost of handling fuel with the best stoker-fired practice, because the handling of coal in stoker installations, which includes the crushing and handling of the coal to the stokers, the cost of power for driving the crushing, elevating, and conveying equipment, stokers, and fans for air supply, together with the repairs on the entire equipment, amounts to from 30 to 60c. per ton coal fired, depending on the size of the plant. Address to Philadelphia Section, American Society of Mechanical Engineers, Oct. 28, 1919, by *H. G. Barnhurst;* published in the *Journal of the Engineers' Club of Philadelphia*, December, 1919.

BLAST-FURNACE FLUE DUST.

BY R. W. H. ATCHERSON.

BLAST-FURNACE flue dust is one of the most troublesome operating factors in the iron and steel industry. Several successful operators claim that it is useless to recharge raw flue dust because the furnace would never have blown it out if it had been suitable material for blast-furnace consumption. Yet some very remarkable results have been attained at the Ohio Works of the Carnegie Steel Co. through recharging raw dust. The plant comprises six modern blast furnaces. Up to 1909, about 300,000 tons of flue dust had accumulated in stock piles. During the last 10 years, there have been recharged into these furnaces all of the flue dust recovered from the furnace operations, the entire stock pile of flue dust, and nearly 80,000 tons of dust shipped from other furnaces of the Carnegie Steel Co.

In common with a great many blast-furnace men, we have tried many schemes for reducing the amount of dust carried out by the gas and numerous ways of recharging it, in both the raw and the sintered state. We have operated on inconsiderable percentages of Mesaba ore and again have used nothing but Mesaba for years at a time. Yet we are still making a great deal of flue dust, probably not any more than the average blast furnace using fine ores, but the amount is out of all proportion to any physical changes in our ores and has never been as low as in some furnaces that are being driven at about the same rate of pig-iron production.

I believe that much of the opposition to the use of fine ores in blast furnaces is superficial and prejudicial. Burdens composed entirely of fine ores are being very successfully handled by furnaces built on lines as developed today. High flue dust production, where prevalent with high percentages of fine ores in the burden, is frequently due to an improper mixing or sizing of the ores. Where no thorough effort is made to counteract the natural segregation of lumps and fines at each rehandling from the mines to the furnace, there is bound to exist in the blast furnaces strata of ore of a finer consistency than contiguous layers. The obvious requirement of these finer and denser layers is an augmented gas pressure, sufficient to force through the denser layer. The action is rather more violent than would be the normal flow of gas and is attended by a greater disturbance of the stock, resulting in a larger production of dust than would follow the passage of the gas through the more open layers of ore. As a means of limiting the segregation of the fines into layers in the furnace, the method of charging is of incalculable value as a corrective feature but is not sufficiently thorough to counteract indifferent handling at the mines and docks. The intimate mixture of each ore into a uniform material physically also brings about a much desired chemical equality.

From any view point, coke is the very life blood on which the whole smelting process depends. The physical structure of the coke has a very much greater influence on every phase of blast-furnace practice than has the structure of any of the other materials. As indicating the effect of soft coke on flue-dust production, a comparative statement is given, covering two operating periods on the same furnace under apparently identical conditions aside from the coking time on the by-product ovens. While using the soft coke, so much of it was dissolved in the furnace stack that it was found advisable to decrease the volume and increase the temperature of the blast and to charge additional coke while it was also necessary to use several times the normal number of scouring charges of Bessemer slag to keep the furnace working smoothly.

TENSILE PROPERTIES OF BOILER PLATE AT ELEVATED TEMPERATURES.

BY H. J. FRENCH, MET. ENGR.

AT the request of a committee of the Engineering Division,[1] National Research Council, a study of the properties of boiler plate at various temperatures up to about 900° F. (482° C.) has been instigated. The paper is a report of preliminary tests made on two grades of ½-in. plate and includes a description of the apparatus used in the determination of the proportional limit. The steels tested were ½-in. (12,7 mm.) boiler plate of firebox and marine grades.

The test specimen was heated by means of an electric tube furnace, two spiral resistors in series being used. The furnace was operated on either 110 or 220 volts direct current, close regulation being obtained by two 15-ohm 30-ampere variable resistances in series in the circuit.

In both grades of plates increase in temperature from 70°

[1]Committee on Physical Changes in Iron and Steel Below the Thermal Critical Range, Dr. Zay Jeffries, Chairman.

to 870° F. (21° to 466° C.) is accompanied by distinct changes in strength and ductility, viz.: (*a*) The tensile strength at first decreases a few thousand pounds per square inch, reaching a minimum at about 200° F. (93° C.). This is followed by an increase up to about 550° F. (288° C.) where the tensile strength reaches a maximum about 10 per cent greater than the normal room temperature value, after which another and final decrease occurs. (*b*) The percentage elongation in 2 in. (5 cm.) decreases rather slowly up to about 200° F. (93° C.) after which it drops more rapidly, until a minimum is reached at about 470° F. (243° C.); this factor then increases throughout the balance of the range under consideration. (*c*) The reduction in area closely follows the inflections registered in the curve for elongation, but has a minimum at slightly higher temperature than the elongation. (*d*) The proportional limit at first increases slightly and shows a maximum in the neighborhood of 400° F. (204° C.) for the firebox plate and the highest values between 200° and 300° F (93° and 149° C.) for the marine plate. It is noted that both the actual and the percentage increase are much greater in the case of the firebox grade and that the subsequent and final decrease in proportional limit for this plate takes place more sharply than in the case of the marine grade of boiler plate.

AN EXPERIMENTAL GUN CONSTRUCTION

By P. W. Bridgman.

During the war, the Navy undertook the construction of an experimental gun embodying features designed to lessen the cost and time of production. These experiments were initiated after representations as to their desirability had been offered by myself, by the Naval Consulting Board, and by the National Research Council. The first drawings were made in June, 1917, and the experiment was completed in November, 1918.

For the sake of clearness it will pay to recapitulate briefly the fundamental idea of gun construction. It is well known that if a hollow cylinder is subjected to internal fluid pressure, the maximum stress occurs in the inside layers, the outer parts carrying much less than their due share of the stress. This inequality of stress is more pronounced the thicker the walls of the cylinder. If such a cylinder is pushed to the elastic limit, failure in elasticity will take place long before the outer layers have reached the limit of their capacity. Economical use of the material would demand, however, that all parts of the cylinder reach the limits of their capacity simultaneously. This may be brought about, at least in cylinders of not too great thickness, by producing in the inner layers an initial compression, and in the outer layers an initial tension. The effect of internal pressure is at first to relieve the compression of the inside layers, while increasing the tension of the outside layers. If the initial stresses are properly distributed, all parts of the cylinder will reach their elastic limits simultaneously, thus giving a cylinder of maximum strength for its weight.

In gun construction as hitherto practiced, this initial distribution of stress is produced either by winding the inner tube with wire, a common English practice, or by shrinking hoops over the innner tube, which has been the standard American practice. Either process is long and expensive.

There is another possible method of producing the desired internal compression. If a heavy cylinder is stretched considerably beyond its elastic limit, the inner layers flow and the outer layers receive a permanent stretch. On release of pressure, the outer layers shrink back on the inner, producing an internal compression, and of course, an equilibrating tension in the outside layers. If now pressure is reapplied, it will be found that the elastic limit has been raised to the previous maximum pressure. It is possible to raise the limit in this way to two or three times the value as calculated by the usual theories. This behavior of cylinders under high internal pressure was demonstrated experimentally, and has been continually used in the construction of apparatus for my high-pressure experiments at the Jefferson Physical Laboratory since 1906. In these experiments I have accurately measured hydrostatic pressures as high as 300,000 lb. per sq. in. (21,090 kg. per sq. cm.), pressures which would have been unattainable except for this behavior of thick cylinders when stretched beyond the elastic limit.

With regard to gun fabrication, it has been demonstrated by actual construction and firing tests that it is possible to make a gun from a single forging, producing the required distribution of internal stresses by a preliminary application of hydrostatic pressure so high as to strain the material considerably beyond its yield point. The great simplicity of construction by this method leads to the expectation of important economies of time and money if quantity production should be attempted.

The technique of controlling the pressures required, which are of the order of 100,000 lb. per sq. in. (7030 kg. per sq. cm.), has been described as applied to the experimental gun. The essence of the technique is a packing which automatically becomes tighter at higher pressures. There is no reason to think that the technique should not be successfully applied on a commercial scale.

The behavior of the hollow cylinders composing the gun, when stretched by heavy internal pressure, has been described. Such cylinders flow and receive permanent set under pressures which may be about twice the elastic limit computed according to the simple theories. After once stretching, the cylinder receives little or no further permanent set up to the previous pressure maximum. Within this range of pressure, the cylinder behaves in a manner approaching that of perfect elasticity, but with very marked disturbances, of which hysteresis and accommodation effects are the most prominent. These disturbances tend to disappear with time. The approach to perfectly elastic behavior is much closer for thin than for thicker cylinders. A valid theory of the stress-strain relations under such conditions is much to be desired, but has not yet been formulated.

USE OF MICROSCOPE IN MALLEABLE-IRON INDUSTRY.

By Enrique Touceda.

As in the case of steel and the non-ferrous alloys in general, the use of the microscope in connection with the manufacture of malleable cast iron has proved of inestimable value to the industry. No fairer statement could be made than that the start of real progress in the industry was coincident with the application of metallography to the product.

The writer has been associated with the manufacture of malleable-iron castings since 1894. In 1904, he became convinced that while practical experience combined with close observation, when accompanied by a good metallurgical foundation, made possible the explanation and elimination of many of the troubles encountered, works' control could never be satisfactorily attained without proper facilities for a study of the structure rather than the fracture of the annealed product. Steps were then taken to secure the best metallographic outfit available and, with the aid of a small electric-resistance annealing furnace and this outfit, more knowledge was obtained in 3 months than in the previous 10 years.

It must not be assumed, however, that in all cases dependence on the use of this instrument alone will disclose the true and complete story, for what may be shown by the fracture, the structure, and the chemical composition must, in many instances be carefully considered before an accurate diagnosis can be rendered.

UNWATERING THE TIRO GENERAL MINE BY AIR-LIFT.

By S. F. Shaw, E. M.

In 1913, the Tiro General mine, at Charcas, S.L.P., Mexico, which had been making from 125 to 150 gal. of water per min., was allowed to become flooded, after all the pumps had been

removed, and in 1918 the problem of unwatering it came up for solution. There are two vertical shafts, the Tiro General, 1390 ft., and the San Fernando, 1225 ft. in depth, with five connecting levels between them. The San Fernando shaft had been partly retimbered while the Tiro General had been newly timbered from the collar to 1090 ft. in depth. It had been possible to place guides in only one compartment of the Tiro General, from the collar to the 7th or 850-ft. level, to which it was necessary to lower the water before station pumps could be installed. Soundings indicated that compartments in the Tiro General were open to 1082 and 428 ft., and in the San Fernando shaft to 471, 488 and 586 ft. The water had risen to a point 140 ft. below the collar of the Tiro General shaft.

The steam plant at the Tiro General shaft includes one 300-h.p., one 150-h.p., and one 100-h.p. Erie City water-tube boilers, and two 160-h.p. Heine water-tube boilers. All but one of these boilers were supposed to be in good shape, but it was soon discovered that six years of idleness in a climate that is foggy for several months of the year had left them in poor condition. The compressed-air plant comprises one Nordberg cross-compound compressor with piston displacement of approximately 2,500 cu. ft. of free air compressed to 96 lb. per sq. in., and another Nordberg cross-compound with piston displacement of 1,235 cu. ft. of free air, to the same pressure.

The main pump station is on the 7th level where had been installed a Prescott potvalve plunger pump with capacity of 200 gal. per min.; also a Gould triplex plunger pump with capacity of 135 gal. per min., driven by a 6½ by 10 by 12 in. steam engine. From the lower levels the water had been raised to the 7th level by small station pumps and sinking pumps.

Although the submerbence of an air-lift pump at the final stage of unwatering to the 7th level would be limited to about 225 ft., we were assured by pump manufacturers that this point could be reached by a single-stage air lift, and we therefore decided to adopt this method. The equipment to be purchased consisted only of piping, foot pieces, etc., since the compressor plant was considered adequate for the purpose. Not only did we save the first cost of such equipment as sinkers, or centrifugal pumps and motors, but we also found that delivery of pipe could be effected in much less time than pumps and motors.

At the beginning of operations, two air-lifts were installed, one in the Tiro General and one in the San Fernando shaft. These were operated until it became evident that they were not suitable for the work to be required of them at greater depth; they were then removed and replaced by air-lifts of better design, designated No. 3 and 4. Since the lift involved in lowering the water to the seventh level, where steam pumps could be installed, was much greater than had ever been attempted before where a large quantity of water was to be handled, it was necessary to make many careful experiments as the work progressed, in order to anticipate the probable performance of the lifts that were installed.

LOW-TEMPERATURE CARBONIZATION OF COAL.

By S. W. PARR and T. E. LAYNG.

THE low-temperature carbonization of coal involves the carrying out of the coking process under conditions wherein neither the coal mass nor any of the passageways through which the volatile products pass are heated above 700° or 800° C. For convenience in this discussion, the single number 750° will be used to designate the maximum range. This temperature is not selected arbitrarily; it is the result of certain natural conditions that are inherent in the substances involved. Two of these conditions are sufficiently pronounced to suggest a line of demarcation at this point as follows: (1) Below 750°, all the heavy hydrocarbons are expelled, which means that, at these lower temperatures, the illuminants, the gases of high calorific value, and the condensible oils are discharged; above 750°, there are given off the lean, non-illuminating gases consisting for the most part of hydrogen and marsh gas and having no considerable constituents present. (2) Below 750°, there is substantially no secondary decomposition; above 750°, the volatile products are readily decomposed, forming tars, naphthalene, free carbon, etc.

It is acknowledged that the maintenance of these temperature conditions at the present time has only an ideal and not a practical status. Actual operations under these conditions, as an industrial accomplishment, are still in the experimental stage. However, many tendencies are working toward this goal and the topic is certain to be one of great interest until we have come much nearer the ideal in practice. There is a definite value, however, in setting forth in quantitative terms, so far as they may have been determined, the factors that represent the normal yield to be expected if conditions are maintaind as planned.

Attention is called to the following facts: The temperature conditions were maintained consistently throughout so that uncertainty on that point is eliminated. The yield of by-products from a given type of coal is sufficient in form to afford strong presumption as to the fact that these are the normal values that may reasonably be expected under low temperature carbonization conditions. The tars are of unusual interest and require further study to arrive at full information concerning this product. The gas yield represents usually high calorific values. The behavior of the sulfur is, in some respects, the most important of all the data. The coke is, in many respects, the most interesting product of all. It is sufficient at this time to say that the so-called non-coking coals of Illinois give promise of being advanced into the class of coking coals.

THE COEFFICIENT OF EXPANSION OF ALLOY STEELS.

By JOHN A. MATHEWS, Ph.D. Sc.D.

DURING the prosecution of the aircraft-production program in 1917 and 1918, the writer visited many plants engaged in the manufacture of motors, planes and parts, in carrying out his duties as chairman of the Committee on Aircraft-engine Forgings. While the coefficient of expansion is not without its effect in volume changes in hardened steel, it is not a determining factor in the matter of distortion and going out of shape. Irregular heating, uneven furnace bottoms, and carelessness in withdrawing the part from the furnace, as well as the manner in which the part enters the quenching bath are of greater moment. Generally speaking, also, steels of relatively low hardening temperature will distort less than those requiring higher hardening heats. The coefficient of expansion must be considered in engineering design most frequently when different metals or alloys are used in the same construction. For example, the difference of expansion between a steel crankshaft and an aluminum crank-case might be of real importance and a steel with no coefficient of expansion would be much less desirable than one with the normal coefficient.

Through the coöperation and assistance of Major Heaslet and Capt. H. F. Wood, of the Detroit Branch of the Aircraft Production Department, the Committee was assisted in securing various types of alloy steels used for crankshafts; and in connection with them we have the analyses and tensile properties, also the hardness and shock-test values in several cases. The writer has supplemented this list with other types of alloy steels frequently used for axles, shafts, etc.; all of this material has been tested in a heat-tried condition, which has produced elastic properties between 100,000 and 150,000 lb. per sq. in. yield point. The Bureau of Standards coöperated with the Committee and made the actual tests of coefficient of expansion, which is a sufficient guarantee of the accuracy of the figures presented. We hope the complete data presented may prove of value to engineers and that future authors, in presenting data on the same subject, may follow the example we have set.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

GERMAN CHEMISTRY.

THE one excuse for again directing attention to the brand of chemistry which has been so well advertised is the apparent determination of Germany to regain the world markets which she once held due to the application of science to her commercial problems. There are still some who feel that there is a certain potency in German chemistry which we cannot expect elsewhere and hence we refer to the article entitled "The German Chemical Myth," by Benjamin T. Brookes, which appeared in the *North American Review* of November, 1918, and Mr. Townes R. Leigh's article on "Germany's Stolen Chemistry," which appeared in *Drug and Chemical Markets*. These gentlemen point out to what extent German chemists have failed to take part in work on the fundamentals of chemistry. In laying down twenty-one fundamental laws by which the science is governed, such men as Avogadro, Boyle, Charles, Dalton, Faraday, Henry, Mendelejeff, van't Hoff, Dulong and Petit appear, but nowhere is the name of a German to be found. Holland, Russia, Italy, France, England and America all appear.

The discovery of chemical elements shows at once what a small number of the useful ones have been discovered by Germans. Oxygen is credited to an Englishman; the discovery of nitrogen to a professor at Edinburgh University; carbon dioxide was isolated by a Scotch chemist; and the other rarer elements of the air were first discovered and studied by British subjects. Nor have the Germans discovered the elements of water—both hydrogen and oxygen having been first recognized as elements by Englishmen. Chlorine was discovered by Sheele, a Swede, and sodium, the other component of salt, by a Londoner, Davy.

In Buckley's "History of Natural Sciences," thirty of the chief men of science of the 17th century included but three of German blood. Twenty-seven of the 18th century include again but three Germans, and the majority of the important contributions to chemistry during the 19th century were not made by sons of the Teuton Empire.

If one considers the question by subjects, Professor Brookes points out that in the field of dyes every one has had a hand, but the origin was through Perkin in England. It was van't Hoff of Holland who first showed the Germans how to develop their potash natural monopoly. The phosphate industry, petroleum, and radium from carnotite ores are American. Nickel and cobalt are American and Canadian. The cyanide process so important in metallurgical operations is attributed to McArthur and Forrest in South Africa; electro-chemistry and aluminum to Hall, an American, and Heroult, a Frenchman. Artificial graphite and abrasives are American, cement is English and American, and the development of the use of powdered coal which made cement a possibility in Germany, is likewise an American invention. Hydrogenation, which one pro-German writer called a beneficial result of militarism in that large supplies of hydrogen made for balloon purposes could be used for the process, is French in its origin. Artificial resins are to be credited to a Belgian working in America, and to a Frenchman we credit organic compounds of magnesium.

Radio-activity, electrolytic dissociation, electrochemical action, spacial isomerism laws in heterogeneous systems, the law of atomic heats and of mass action, together with the law of conservation of mass and the atomic theory, are all of other than German origin, as is also the fundamental work on gases. It is seen therefore that while the fundamental work on chemistry has been almost universal, German names are conspicuous by their absence, and their prestige is really to be found in lexicons, text-books, tables of constants, not always too well done, and careful systems of systematic instruction. So far as ability is concrened, it should be apparent that the rest of the world is perfectly able to take care of itself; but chemists need assistance in preparing for themselves the kinds of things in which Germany has had a monopoly. We refer particularly to the compilation of Tables of Critical Physical and Chemical Constants and the preparation of other compendia of scientific knowledge more complete, more accurate than have appeared heretofore and in the English language. The English-speaking people are coöperating on this work, but there is need for material support in the undertaking that is so large and yet so important that industry can properly be expected to do its part.

ANTI-DIMMING COMPOSITIONS.

ATTENTION is called to the contribution of P. W. Carleton to the December, 1919, issue of the *Journal of Industrial and Engineering Chemistry* on the subject of anti-dimming compositions, primarily for use in gas masks. There is also a contribution from the Chemical Laboratory of Oberlin College on the same subject in that number of the journal. It seems reasonable to expect that some commercial applications may be made of the principles which have been established and the formulae which have been devised.

Inasmuch as good vision is one of the important properties of the gas mask, it early became apparent that some device must be invented which would prevent the rapid dimming of the various types of eye-pieces used in gas masks. A considerable number of people worked upon this problem.

Some of the requirements which a satisfactory anti-dimming composition must fill are: "It must be soluble in water and reduce the surface tension of water so that moisture will not form drops on the lens. It must be easy to apply. Its method of application must be fool-proof, so that if possible an unsuccessful application will be impossible. One application must last a long time, several hours of consecutive use. It must function properly several days after its application. It should be put up in a convenient outfit which should have but few parts and should not be fit for other uses. Obviously the unit should be cheap." It is interesting to note that one of the first anti-dimming compounds was in the form of a stick which was put up in a little tin box, strong and well made, and this holder became so attractive as a receptacle for matches or cigarettes that without thought of future safety, the sticks were discarded and the holders put to new uses.

A variety of formulae were used, the stick to which reference has been made having a formula: 100 parts 85 per cent turkey red oil; 15 parts caustic soda; 5 parts water glass; and 5 parts paraffin oil. This product contained from 10 to 20 per cent of moisture. Later sodium carbonate was substituted for the caustic soda because of the harmful effect of the caustic upon the hands.

Another formula, in addition to the ingredients above named, added 23 parts of glycerine and required a different method of application. The surfaces of the eye-piece were wiped clean, and after breathing on the inside surfaces, a very small amount of the composition was applied, rubbed in thoroughly with the finger, and then gently polished with a cloth.

The work at Oberlin was undertaken at the suggestion of the National Research Council, and involved an elaborate study of some nine points. These were: Studies of the sul-

phonated glycerides of saturated and unsaturated fatty acids, as well as sulphonated fatty acids; of the relative merits of the different alkali salts of the sulphonated fats; of soaps of the saturated and unsaturated fatty acids; of Twitchell's sulpho derivatives; of the effect of excess constituents in preparing anti-dimming sticks; the relation of surface tension lowering to the desired anti-dimming effect; the influence of solubility on the lasting power of anti-dimming sticks; the effect of varying thickness of the anti-dimming film, and more rapid and accurate methods of testing.

The results obtained from these studies appear in the original article and it is pointed out that soaps in general are improved by the addition of a few per cent of glycerol, 10-15 per cent of alkali, and a small quantity of marine oil. The sodium silicate or water glass serves well as a binder. The soaps from a variety of vegetable oils all show excellent film-forming properties, and the final recommendation concerns anti-dimming preparations made from sulphonated rape seed oil and sulphonated cotton seed oil.

WHAT A FLOUR CHEMIST DOES.

IN the *Chicago Bulletin* which is issued by the Chicago Section of the American Chemical Society, we find in Number 8, Volume 6, an outline of some of the things a chemist who specializes in flour is called upon to do. The greatest emphasis is placed on baking tests. The loaves are allowed to rise to the greatest possible extent, since the size of the loaves gives important information as to the so-called strength of the flour. As a result, the loaves are of very coarse grain.

Many analyses must be made and certain facts have been determined, although there remains much research to establish new data. To quote from the article mentioned:

"*Moisture.* Moisture should not exceed 13 per cent. Flour with excessive moisture is more likely to become sour or musty, especially in warm weather or in unventilated or damp storage.

"*Acidity.* The percentage of acidity (calculated as lactic acid) is an approximate measure of the soundness and keeping quality, or in the case of flours bleached by chlorin-containing gases, of the amount of bleaching given. A small increase in the amount of acidity present might not render it unfit for use, but indicates a somewhat diminished ability to keep well if storage conditions are adverse.

"*Soluble Carbohydrates.* Soluble carbohydrates (sugars, dextrins, etc.), are the fermentable materials and in sound flours do not usually exceed 6 per cent. Flours made from sprouted wheat have increased amounts of soluble carbohydrates. If soluble carbohydrates are present in less amount than about 1.2 per cent, the loaf made will usually have a pale crust or require extra amounts of sugar in order to take a normal brown.

"*Gluten.* Low grade flours have more gluten than higher grade flours made from the same wheats, though they are usually of inferior quality. Soft glutens lack the ability to spring and will not stand a long fermentation with yeast. Flours high in gluten of elastic quality require longer or more vigorous fermentation than those with less gluten.

"*The Baking Test.* The test loaf is made by a special formula and baked in an expansion test pan designed to give the gas-filled dough maximum opportunity to expand and to exhibit its stability. It is not the intention to produce a loaf of the same qualities, close-grained texture and shape produced commercially, but to bring out and emphasize the individual merit or demerit of the flour. Test loaves having a volume of more than 180 cubic inches (2,950 cubic centimeters) are to be considered strong and satisfactory for bread making and those of 200 cubic inches or more (3,277 cubic centimeters) as o superior strength. A variation up to 5 or 6 cubic inches is of little significance, owing to the complexity of yeast fermentation processes and the fact that yeast is a vital organism variable to some degree in strength.

"*Volume.* The volume indicates the ability of the flour to expand, hold up well and give a light, well-piled loaf, and if necessary stand a reasonable amount of unfavorable treatment.

"*Weight of Loaf.* The weight of loaf is taken as it comes from the oven and shows the ability of the flour to hold the absorbed water and make a good bread yield to the barrel of flour. Yields are strictly comparative, but due allowance must be made for the continuous shrinkage in weight of loaf from the time of weighing. The water used shows the actual absorbing and retaining capacity of the flour in baking. Due consideration must be given to the moisture content and age of the flour, freshly milled flours usually having less absorption and bread yielding ability than older flours."

THE WORK OF THE FOOD CHEMIST.

IN *Chemical Age* for December 10th there is an interesting discussion by L. M. Tolman concerning the "Work of the Chemist in the Food Industries." As Dr. Tolman points out, a survey of the last twenty years in the development of chemistry and scientific control in the food industry, would indicate that the most important work has been accomplished along the lines of preventing spoilage and decay. A great deal has been learned regarding the cause of spoilage and quickly following that work has come the development of methods to remove the cause. Much of this work has been done in the Bureau of Chemistry, as well as in the laboratories of those who prepare food on a large scale and in the universities.

At the present time the Bureau of Chemistry numbers among its research problems the following investigations with respect to food; the cause of decay in poultry and eggs; the handling and care of broken eggs, first to determine their fitness for food, and second to improve methods of freezing, drying and storage; a study of the methods for handling poultry as regards cooling, chilling, packing, transportation and storage until they are marketed; a general survey of the questions relating to the deterioration of food products from the time they leave the farm until they reach the consumer. There is a similar investigation with reference to fish and the effect of low temperatures during the different periods of storage. Special attention is being directed toward the sardine industry and the sanitary and hygienic methods to be employed in packing.

The National Canners' Association laboratory has been actively engaged in studies upon the types of micro organisms responsible for spoilage in canned foods in an effort to develop satisfactory methods for complete sterilization that will leave the contents of the can attractive in appearance.

There has been a vast amount of work done upon milk to the end that notwithstanding the difficulties inherent in our modern long-distance transportation of this food, safe milk may be delivered in our large cities. Just imagine for a moment what would be involved if a city had to depend upon the distribution system of the small town or upon the primitive method in vogue in parts of the old world where the milk goat is driven to the door and milked!

It may be news to some that the frying of doughnuts is an exact science and as Dr. Tolman says, "To give the best results it must be carried out at a definite temperature for each individual kind of fat, and with the different methods of making the dough. The working out of these conditions has to be done with much more exactness than is ordinarily done in the kitchen. So that we find the large producers of lards, cooking oils and compounds first work out the best methods of using their products in pies, cakes and bread before they send out their directions for using. In this way we find the chemical laboratory expanding its work so as to include the trained domestic science worker."

The problem of the food chemist is frequently very complex. Many industries have actually begun in small kitchens with the producers personally marketing their product. To maintain the same characteristics in such products when pre-

pared on a commercial scale is sometimes difficult, for foods must be not only nourishing and attractive in taste, but must maintain an appetizing appearance. Flavor is a very delicate quality and when once the public taste has been cultivated all precautions must be taken to maintain the taste unimpaired.

Just as the prevention of spoilage has been the outstanding feature of the last twenty years, so Dr. Tolman predicts that during the next period we may properly expect unusual developments due to recent work with those indefinite substances called vitamines, the influence of which upon body growth and maintenance has been proven so conclusively in experiments not only upon laboratory animals but in, many cases, upon human beings.

SCIENTIFIC INSTRUMENTS.

The United States Tariff Commission has compiled information concerning scientific instruments for the use of the Committee on Ways and Means of the House of Representatives, and in this is brought together considerable information of interest to the chemist. For example, the many paragraphs under which scientific instruments are mentioned in the Tariff Act of 1913 are brought together in one place where a comparison of rates of duty on the different materials of interest to the laboratory can be made. The articles included under the term scientific instruments are very diverse. Such instruments are characterized by a high degree of sensitiveness and the dependability with which they serve their various purposes. They are instruments for the measurement of weight, volume, length, heat, temperature, light, color, and time. A great many instruments are electrical, either because of their employment in relation to electrical phenomena, or by reason of the use of electricity in the determination of other phenomena. The continued application of scientific methods to industry has developed a new and extended demand for scientific instruments which were formerly little known outside the laboratory of the student. We now have many kinds of engineering, physical, chemical, and medical instruments.

In the manufacture of such instruments the major portion of the raw material is metal and glass but porcelain, wood, rubber, different sorts of insulating materials, quartz, feldspar, and calcite may also be mentioned. The methods of manufacture employed in the United States do not differ materially from those abroad, but it is evident to many that if the industry can be developed to the point where quantity production can be undertaken, our manufacturers can then provide the necessary tools and in some cases automatic devices that will permit the production of high-grade instruments on the American system, which should greatly reduce the cost of manufacture, now a handicap in competition for both domestic and foreign custom. For example, there has been no such opportunity to standardize and to put the scientific instrument industry on a great producing basis as has been the case with automobiles, sewing machines, typewriters, and similar apparatus.

The census indicates that there were 197 companies, with a total capital of thirteen million dollars, as producers of scientific instruments, excluding medical and surgical instruments, in 1914. Seventy per cent of these establishments are to be found in New York, Illinois, Pennsylvania and Massachusetts.

The conditions of war have changed some classes of instruments from the exclusively imported to the exported side of the books and scientists generally, as well as the manufacturers, are now concerned with the question of keeping our scientific instrument industry on a basis that will provide domestic needs and also permit exportation. To do this without placing an undue burden upon educational institutions is one phase of the problem, for notwithstanding the greatly increased cost of production abroad, it still costs more to make devices of this kind in the United States, although in some instances, notably chemical glass ware, the quality of our American manufactured material is better than that which heretofore came from across the pond.

QUEBRACHO.

The Latin American Division of the Bureau of Foreign and Domestic Commerce has recently reported upon the quebracho industry as it is found in South America, Argentina and Paraguay being the two most important countries. The following is abstracted from that report:

Quebracho is one of the natural monopolies of South America, just as potash has been a natural monopoly of Germany and jute of India. It is a distinctly South American wood, but is confined to a region of some 300,000 square miles near the central part of the continent, particularly northern Argentina and western Paraguay. In some of the other countries, notably Bolivia, Brazil and Uraguay, these trees are to be found scattered through the forests, but this distribution greatly raises the cost of operations. It is believed that the present rate of cutting is less than the annual growth, so that there is no immediate danger of exhausting the supply of raw material.

The first appearance of quebracho wood was at the Paris Exposition in 1867 soon after which it began to be used for tanning purposes in Europe. It has been prominent as an important commercial commodity for only thirty years, the exports in 1887 of logs from Argentina being valued at 172,700 pesos, with a high water mark in 1911 when the value was 6,897,000 pesos. The total value exported from South America in 1916 was 19,663,000 pesos. The first trade was established in quebracho logs but in the last twenty-five years the industry of preparing the extract has been built up in South America and is now in a flourishing condition. Notwithstanding this activity, there has continued to be an extensive exportation of logs, particularly to Europe and as the wood is very heavy, it is one of the curious features of the trade that this shipment of logs 6 or 7 thousand miles should be maintained, especially in view of the fact that the expansion of the extract industry in South America could easily provide the requirements of American and European tanners. The answer seems to lie in the fact that certain tanners find it desirable to make themselves independent of the extract producers and in the fact that the quebracho wood contains such a large percentage of tannin that the loss involved in shipping the logs is not great. They are usually carried in sailing vessels at low cost and besides this, the increased skill and experience of the operators and the more scientific methods employed in certain foreign countries made it possible to import the logs and then sell the extract at prices lower than those in Argentina. Before the war Germany, for example, exported 20,000 tons of extract yearly at prices less than those of the extract delivered in Buenos Aires.

In obtaining the extract from the wood the customary method is to reduce the logs to chips by the use of revolving cylinders faced with sharp knives, after which these chips are either placed in vats of water and boiled or are digested in closed copper containers with the use of steam. The resulting liquid, which is very concentrated if prepared by the second method, is cooled, then allowed to stand a sufficient time for settling, or precipitation is caused by the use of chemicals. This process also tends to decolorize the liquid. Now the clear liquid is evaporated until the moisture has been reduced to 50 to 60 per cent if it is to be shipped in liquid form, or to 20 to 25 per cent when it solidifies upon cooling. Approximately 23 per cent of the weight of the wood is represented by the extract.

While quebracho is not indispensable to the tanning industry, it is a very desirable reagent, for it does its work very rapidly, producing results in a few days which are secured by other tanning materials in a period of weeks or months. The importance of quebracho in the war was largely due to this rapid action, and when the demand for greatly increased supplies of leather is not so imperative as it has been, other tanning materials can be used if there is a cost advantage.

QUICK-HARDENING CONCRETE.

P. H. Bates of the Pittsburgh branch of the Bureau of Standards, has reported the results of some of his researches on cements capable of producing quick-hardening concrete. These materials are prepared in a manner similar to the method employed in making ordinary Portland cement, but their composition differs considerably in that they are composed principally of lime and aluminum. These calcium aluminates are very high in alumina and while they do not have a very rapid initial set, they do harden quickly and therefore produce high strength within a short space of time. For example, one of the mixtures has a strength of 3,145 pounds per square inch for a 1:6 mixture. tested in the form of a six by twelve-inch cylinder at the end of twenty-four hours, 6,100 pounds per square inch at the end of seven days, and 8,220 pounds per square inch at the end of one year.

There are also a number of tests reported with concrete in which "Sorel cement" was employed. These cements are prepared from light calcium magnesium and magnesium chloride solution and in twenty-four hours such a cement develops strength nearly equal to that shown at the end of seven days by a similar concrete in which Portland cement is employed.

Such cements cannot be used where the resulting concrete is expected to withstand prolonged action of water, but they do commend themselves for certain special uses where a concrete must not only harden in a brief space of time, but also develop high strength. The Sorel cement concretes cannot be frozen and temperatures below freezing, while retarding setting, do not interfere with the action of the cement and no special precautions need be taken in protecting the material when used at low temperatures. The preparation of foundations for guns is but one of the many examples of the special uses for which such materials can be employed and as such an amount of moisture as is usually present in the air does not materially affect the strength, it appears that other considerations than quick-hardening may make them very desirable.

In the case of the Sorel cement concrete, hardening takes place as the result of the reaction between the magnesium chloride and the magnesium oxide. Hence the importance of having the correct proportion between these two magnesium compounds in preparing the cement and concrete. In the case of the calcium aluminates, it appears that hydrated alumina, and calcium, when formed under the proper conditions, constitutes the greater part of the binding material of the compounds. The higher the alumina content in the aluminates, the slower will be the action with water forming the hydrated alumina, and consequently the slower will be the time of setting.

The results of Mr. Bates' work were reported before the American Society of Testing Materials and will be found in the Proceedings for 1919.

SMELTER WASTES.

In many instances so-called industrial wastes can be recovered, but there is frequently the question of what to do with them. Manufacturers can hardly be expected to go to the expense of recovering large quantities of material for which there is but a limited demand and apparently small prospect for developing new uses. It has been pointed out that if all the arsenic was to be recovered from smelter fumes, the mere storage of this poison would become a considerable problem. The same has been true of the sulphur dioxide from the stack gases of smelters which are naturally located at points at considerable distances from possible markets.

In the December issue of the *Journal of Industrial and Engineering Chemistry* it is noted that the Forest Products Laboratory has suggested the possibility of utilizing liquid sulphur dioxide which could be prepared from these stack gases for the manufacture of sulphite acid for the paper industry. Liquid sulphur dioxide would not present a difficult transportation problem and possesses many advantages over sulphur for the purpose mentioned. For example, this liquid sulphur dioxide from the smelter product is free from all foreign material with the exception of a very small percentage of moisture. It could be produced in quantities exceeding the demands of the sulphite industry and its use would conserve sulphur and sulphur-bearing materials now employed.

The paper industry has also been suggested as a possible outlet for the excess chlorine gas sometimes produced in the manufacture of sodium hydroxide from brine solutions. Certain mills have already installed their own bleach plants, finding it more satisfactory to produce chlorine products at the mill than to transport them, but there are still a number of mills which might find it profitable to experiment with liquid chlorine in preference to the bleach with which they are so familiar.

FIRE-PROOFED TIMBER.

Notwithstanding extensive uses of metals, concrete, and other non-inflammable building materials, a vast quantity of wood continues to be used, and it is still important to devise methods for reducing the fire risk. An English company has announced the perfection of a process which consists in first removing the air, moisture and sap under heat and vacuum treatment, and then impregnating the wood with a mixture of non-inflammable chemical solutions which replace the materials previously removed. The final treatment dries the wood, causing the chemicals to crystallize and then these crystals to form a coating which excludes oxygen, thus rendering ignition an impossibility. It is claimed that the higher the temperature the greater the expansion of these crystals throughout the wood, so that while excessive temperatures may cause charring, there is no flame. It is also stated that no detrimental effects are imparted by this treatment, that the wood can be nailed or have screws inserted, finished by any of the approved processes, resists warping and deterioration as well as changes due to atmospheric conditions. The figures as to costs have not been published in detail, but no doubt the cost of treatment is not excessive considering the many resultant advantages.

PRICE OF GERMAN CHEMICALS IN GERMANY.

According to a recent issue of the *Leather World*, an English publication, the prices of chemicals in Germany and especially those used in the production of leather, have risen enormously. This may be illuminating to a few Americans who have been longing for the return of the days when it will be possible for them to again import German supplies at the old figures. The rise in price is due partly to the central offices which have increased some of the prices by fifty and sixty per cent, and it is impossible to ascertain prices far in advance, as they vary within wide limits according to the buyers and sellers in different districts. One kilo of soda, for example, is now five marks in Germany as against eight to ten pfennigs in pre-war days, and there seems to be little, if any, prospect for early improvement in the situation.

INSULATING VARNISHES.

The *Electrical World* publishes a note accompanied by a table giving the characteristics, solvents, and drying time of several varnishes suitable for insulating material. Dielectric resistance is said to increase directly with the length of baking or time required for drying, and it has been found that the slow drying varnish imparts the highest degree of insulation, producing a flexible, tough film which has high mechanical strength and considerable durability. Black varnishes seem to produce better insulation than clear varnishes of the same class. Of course, varnishes should not crystallize under prolonged vibration.

PAPER BOTTLES.

Although bottles of glass have always seemed rather cheap, those who are looking ahead begin to realize that the cost of fuel may some time soon so greatly increase the cost of glass that other types of containers must be considered. The desirability of a one-time or single service container is also obvious and considerable research has therefore been done upon a paper or wood fibre bottle.

Many devices have been invented, some of which depend upon forming the wood fibre on the outside of a collapsible mold through the use of suction. The raw material in most cases has been the same—pulp, or waste paper reduced to a pulp, forms the basis of most of it, and the remaining problem is that of proofing the container against the materials which are to be placed in it, having the proper consideration for low cost and an odorless, tasteless material.

A recent invention provides for blowing the pulp into the desired shape and drying the container by the use of superheated steam or air. It is stated that with the automatic machinery which has been developed one dollar's worth of ground wood pulp will produce 2,133 one-pint containers at a total manufacturing cost less than that involved in merely gathering and washing the usual pint milk bottle.

ANALYSIS OF GERMAN AIRCRAFT FUEL.

In a recent paper read before the French Academy of Sciences particulars are given regarding the composition of the aviation gasoline employed by Germany. Analyses taken of twenty-two separate samples have given the following result: Aromatic carbons, 10 per cent; saturated cyclic carbons, 10 per cent; acyclic carbons, 56 per cent.—Abstracted by *The Technical Review* from *La Nature*, Nov. 22, 1919.

FURTHER DYE DEVELOPMENTS.

Attention is again called to the dye question and particularly to the hearings which have been held before the Senate Committee in connection with the Longworth Bill, passed by the House and now before the upper body. The question which has been so frequently asked by those opposed to the licensing system, namely: "Why did Dr. Herty fail to obtain the dyes for which he journeyed to France?" was fully answered in the testimony of the Alien Property Custodian, F. P. Garvan, who was able to produce a copy of the cablegram sent by German agents in this country to von Weinberg, from whom Dr. Herty had received certain options. The cablegram in question stated: "We fully expect modification Government regulation which will permit us to confirm our orders. This will enable you to maintain your position that all goods to this country outside reparation goods should come to us." Five days after that cablegram was sent von Weinberg cabled: "Sorry we cannot renew your option." Shortly after this, information came to light making it clear, as Mr. Garvan pointed out, that it was not a question as to whether we shall have a license system, but merely whether this license system shall be an American one or one controlled by Germany. The German agents realized the damage that had been done by the cablegram exchange and later on von Weinberg again cabled renewing the options.

The hearing in question was one of greatest interest and a mass of testimony was introduced to show the importance of the dye industry to the medical profession through the accompanying research work on organic compounds, to biologists, and as an agency for defense due to the ease with which plant and experience can be turned to munition production in time of need. It is difficult to see how anyone can seriously oppose the steps needed to insure these advantages for us.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the Scientific American Monthly

THE WORK OF THE BUREAU OF STANDARDS IN TESTING AIRPLANE ENGINES.

The difficulties which surround the successful testing of an engine designed for service in an air craft are perhaps not generally appreciated. The successful testing of stationary steam or gas engines presents no particular difficulties, and even in the case of locomotives, laboratory dynamometer tests have been carried out with success for many years. The peculiar conditions under which aircraft engines are called upon to operate are the main causes of the difficulty in carrying out successful laboratory investigations. Such engines do not ordinarily work under the conditions encountered near the surface of the earth but perform most of their duty at altitudes ranging from a few hundred to 30,000 feet or more. Atmospheric pressures and temperatures are very different at high altitudes from those existing at the earth's surface, and both have a great influence on the operation of an internal combustion engine. The amount of explosive charge which the engine is capable of drawing into its cylinders varies with the density of the air, and this, of course, changes with the altitude. Temperature is also a controlling factor, and besides affecting the quantity of the charge drawn into the cylinder, also produces numerous other variations in the operation of the engine, such as those brought about by the reduction in temperature of the circulating water, the oil, etc.

Over two years ago, it was decided that an extensive investigation of aircraft engines under altitude conditions ought to be carried out, and in coöperation with the National Advisory Committee for Aeronautics, the Bureau of Standards constructed what has since become known as the "Altitude Laboratory." Briefly, this consists of a small concrete room constructed with walls of sufficient thickness and so reinforced as to resist a considerable pressure from without. The chamber is provided with two large doors on opposite sides, arranged to close upon rubber gaskets, so that they are practically air-tight when shut. Within this chamber a stand is placed, so arranged that upon it can readily be mounted any ordinary type of aircraft engine. Means are likewise provided for withdrawing the air from the interior of the chamber, and also the exhaust gases from the engine by means of a vacuum pump. The engine is connected through a flexible coupling with a shaft passing through the wall of the chamber to an electric dynamometer mounted outside the latter. The power of the engine is thus absorbed and may be readily measured.

The air which supplies the carbureter first passes over a bank of refrigerating coils placed above the altitude chamber and its temperature is thus reduced to a point approximating that which would be met at the altitude under which the test is to be conducted. Since by means of the refrigerating plant alone, the temperature cannot be controlled with sufficient accuracy, electrical heating grids are likewise mounted in the air pasage and thus the air's temperature may be held substantially at the figure desired. Similar cooling coils are installed within the chamber itself and fans driven by electric motors circulate this air past the engine, thus simulating the

conditions of an actual flight. As before mentioned, the exhaust gases from the engine are withdrawn by means of a vacuum pump. They are first cooled, however, by injecting water into the exhaust pipe at some distance beyond the engine connection. This water is again separated from the gases before they enter the pump.

The equipment for measuring conditions surrounding the operation of the engine is unusually complete. Thermocouples have been located at all points where it is of importance to determine temperatures, and by means of a manometer board the pressures on both the intake and exhaust sides of the engine, as well as within the chamber, may readily be determined. Weighing tanks are provided for the fuel and a meter is placed upon the air inlet of the carbureter to determine the air flow to the engine. Since it is possible to determine with ease the total heat units in any given fuel, and since the heat equivalent of the engine's brake horsepower may be likewise calculated, it is possible to state with accuracy the brake thermal efficiency of any type of internal combustion engine.

The heat losses which occur are also easily measured, since the total amount of water passing through the jackets and its rise in temperature are recorded as well as the amount of water used to cool the exhaust and the change in its temperature. The only undetermined heat loss is that due to radiation of the sufaces of the engine, but this is known to be extremely small.

This plant has enabled the Bureau to make observations on aircraft engines under conditions closely approximating those met with in actual flight, and yet without any great amount of difficulty and surrounded with all the necessary laboratory appliances. Investigations have been conducted to determine the relative merits of various types of airplane fuels and the work in the altitude laboratory largely influenced the drawing up of specifications for the so-called "fighting grade" of gasoline used by our Air Service during the war. Many investigations have been conducted on aircraft engines and their appliances and much of the development work on the Liberty motor was carried out in the altitude laboratory.

The work above described has almost an equal importance in peace times, owing to the ever-increasing number of air craft in use, and because of the fact that under ordinary conditions economy in fuel and durability during long periods of service is of even greater importance than in war.

The original altitude laboratory consisted of a single chamber as described above, housed in a temporary wood and stucco building. This has now been replaced by two chambers forming a part of the equipment of the new dynamometer laboratory of the Bureau of Standards. The two chambers are so connected that they may be used separately or together, that is, both sets of pumping equipment may be used to withdraw the air and gases from one of the chambers, thus allowing the testing of very large engines.

It is expected that a very complete program of investigation will be carried on and it is believed that the work will be of the greatest importance, not only to the aeronautic industries, but to all those interested in the fundamentals connected with the performance of internal combustion engines.

INVESTIGATION TO DETERMINE THE HEATING OF CAR WHEELS CAUSED BY THE BRAKE SHOES.

THE type of wheel in very general use under the freight cars in the United States is made of chilled cast iron. This style of wheel has been in use with general satisfaction for over half a century. Failures of wheels of this type are comparatively rare, but it has been noted that on railroads having long grades, quite a large number of derailments have occurred at the bottom of these inclines, apparently due to failure of one or more car wheels. After extensive study of these accidents, it has been determined that the failure of the wheels is caused by heating due to the prolonged application of the brake shoes on the descending grade. This heating is sufficient to set up extremely high stresses within the wheel which ultimately cause cracking and failure.

In order to determine the exact temperature in different portions of the wheel, after prolonged heating of the rim, the Bureau has instituted a complete investigation of this subject. It is obvious that such measurements cannot readily be made upon a wheel in service, and considerable ingenuity has been shown in perfecting a laboratory apparatus capable of producing conditions analogous to those met with on the road. The wheel is mounted in a vertical position and surrounded by electrical resistance coils insulated from but setting close against the rim of the wheel. Holes are drilled in the wheel at all points at which it is desired to obtain temperature measurements and into these openings thermocouples are inserted. The wheel can thus be heated to any desired temperature at the rim, and the corresponding temperatures at other portions easily read. Quite a number of wheels have already been tested and others are being submitted from time to time by parties interested in this work.

FLAT SLAB INVESTIGATION.

THE preliminary work on the testing of the concrete floor, mentioned in the last issue, is being carried forward rapidly. Beginning on November 26, a series of readings of deformation in the steel and concrete were taken three times each day. A total of eighteen gage lines were read each time, these lines being well distributed over the under side of the slab. This work was continued until December 13. The particular object of these special readings was to obtain important information regarding the changes in the stresses due to weather conditions which were very variable at that time. At the time of this writing, the load tests are about to be commenced and in a few days it is expected that the action of the structure can be predicted. The loading material in this case will consist of stacked brick 5 x 8 x 4½ inches in size. The first application of load will consist of one layer of these bricks over all parts of the slab.

A SUBSTITUTE FOR JUTE BURLAP FOR SAND BAGS USED IN MILITARY WORK.

PRELIMINARY laboratory tests have been completed in the investigation of substitutes for jute burlap for sand bags, such as are used by the Army. It has been shown that paper does not equal burlap in tensile or bursting strength, but, nevertheless, it is felt that paper suitably made up into bags may be of value for this purpose. Further tests are to be made on four types of paper, as well as on burlap and cotton fabrics, and all these materials will be subjected to weathering tests. Bags will be obtained, made up of these materials, and will be given laboratory tests and also tests under field conditions.

DETERIORATION IN THE STRENGTH OF PAPER AFTER STORAGE.

As a result of tests on approximately 150 samples of paper, stored since March, 1909, it is noticed that bonds and ledgers containing 100 per cent rag did not deteriorate in bursting strength as much as printing, writing, and similar papers containing wood pulp. The loss in bursting strength for the first class of papers tested was 11.9 per cent, while the bursting strength for the second class was 20.4 per cent less than when tested in 1909.

While these conclusions have been derived from tests on nearly 150 samples, as above noted, a still larger number of additional samples will be tested soon, and the results studied to determine, if possible the cause and amount of the deterioration of paper in storage.

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CLEARING CANADIAN CITY STREETS OF SNOW—REAR VIEW OF A HORSE-DRAWN, POWER-OPERATED SNOW PLOW (SEE PAGE 252)

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DO CALORIES MEASURE THE VALUE OF FOOD?*

By Henry Dwight Chapin, M.D.

As the attention of physicians is being called more and more to problems of nutrition and their solution, it may not be out of place to re-examine some of the foundations of our teachings and see if they are altogether sound.

CALORIES AND FOOD VALUES.

Much is written and said about calories, as the food value of a certain substance is so many calories; and there is a suggestion that a calory is a sort of food ingredient, the real value of food depending on the number of calories present.

A calory is a measure of heat, just as grams, ounces or pounds are measures of weight. If a table of food values was prepared which stated that a definite quantity of milk yielded 6 pounds, meat 8 pounds, bread 4 pounds, and soup 1 pound, the natural question would be, "Pounds of what?" Scant attention would be paid to any one dwelling on the value of particular foods, because the pounds were there. Is it any more rational always to dwell on the value of a definite quantity of food simply because it contains so many calories? The most diverse kinds of food may have the same caloric value but a very different nutritive value.

The calory method of feeding is based on the assumption that nutrition processes depend solely on the oxidation of food, and that the heat given off as the result of the oxidation is the sole measure of the value of the food. In practice, the tendency is to keep a table of calory values from which a diet is made out by an arithmetical process, and the physician is likely to feel that if the calory count is correct, the food problem is properly solved.

In experimental nutrition, however, it is soon found that nutrition is not a simple oxidation process. Many feeding experiments have been conducted with animals to see if food materials from different sources, having supposedly the same chemical composition and yielding the same number of calories as the result of oxidation, have the same practical food value. One of the most notable of these experiments was made by Hart McCollum, Steenbock and Humphrey[1] at the Wisconsin Agricultural Experiment Station with a large number of animals over a period of four years, and some of their remarks and conclusions make interesting reading. They say, in part:

"There is evidence from the data that there is a distinct and important physiologic value to a ration not measurable by present chemical methods or dependent on the mere supply of available energy. While the latter are important and give valuable data for a starting point, they are, nevertheless, inadequate as final criteria of the nutritive value of a feed. . . . Probably none have felt the limitation of mathematically constructed feeding standards more than those who have taken a prominent part in their development, and even the practical and successful feeder uses these standards only as a help, varying the kind, as well as the proportion of total nutrients in the ration to meet the requirements of the individual. The kind of nutrients, however, receives his attention only when their effects are extremely pronounced and immediately apparent. . . . But in addition to the limitation of mathematical standards, which consider only digestible nutrients, or the total net available energy of a ration, there are still other important factors that must be considered. We refer to what may be called the *physiologic value* of the ration. . . . There are many different proteins, in addition to nitrogen-bearing bodies of nonprotein character; fats of different compositions and degree of saturation; carbohydrates of many types; and almost a host of undetermined and undefined bodies in the daily ration of a domestic animal. . . . Unquestionably the *physiologic* value of a ration is largely dependent on its chemical constituents, but the usual determinations made on feeding materials do not reveal the character or manner of combination of many of the constituents. Consequently, the physiologic value can be determined in the present state of our knowledge only by long continued observations of the reaction of the feed on the animal."

Since the foregoing experiments were conducted, animal feeding experiments have been widely carried on, and it seems to be the universal finding that the number of calories a food yields on oxidation is not at all an indication of its feeding value. Bayliss[2] says:

"Heats of combustion do not necessarily give the actual energy value of foodstuffs as available in the organism. . . . In the animal body, energy is derived from chemical combination. This form of energy is readily converted into various other forms without the necessity of passing through the form of heat."

ANAEROBIC AND AEROBIC REACTIONS.

At this point it may be well to call attention to a fact not generally known, namely, that large quantities of the common foods are used by animals by anaerobic metabolism, since air is not essential to animal life in all cases. Mammals and birds quickly die from lack of oxygen. Frogs may remain alive for days in an atmosphere containing no oxygen. Fish and reptiles may live without air for some time, while insects

*Read before the American Pediatric Society, Atlantic City, N. J.

[1]Research Bull. 17, University of Wisconsin Agricultural Experiment Station.

[2]Bayliss, W. M.: Principles of General Physiology, New York, Longmans, Green & Co., 1915.

will live and be active in a vacuum for several days. Leeches can live ten days without oxygen. Bunge[3] says:

"I have made many experiments with the roundworm of the cat, and have satisfied myself that these animals can live in media entirely free from oxygen for from four to five days and be extremely active during the whole time. Whoever has seen these movements must be convinced that oxidation is not the source of muscular energy in these animals."

It is evident that animals which eat the common foodstuffs and obtain energy from them for days at a time in the absence of oxygen do not carry on their vital processes and obtain energy as the result of oxidation, and that for them the amount of heat that can be produced by oxidation of the food they utilize is of no interest.

In the bodies of higher animals it appears that the processes of nutrition are a combination of anaerobic and aerobic reactions. From reading Bayliss it would seem to be fairly well settled that the primary processes in the bodies of higher animals are anaerobic, and that the aerobic processes are secondary. The contraction of the muscles is an anaerobic process:

"There is neither consumption of oxygen nor evolution of carbon dioxid. It is not an oxidation process. . . . To restore the potential energy which the system has lost in contracting, energy is supplied by another reaction of a chemical nature, which succeeds the contractile stage. . . . The energy required for the second process is afforded by a reaction in which some substance, carbohydrate or fat, is oxidized. Much oxygen is used and carbon dioxide given off. . . . Consideration of life without oxygen leads to the view that the actual source of the free energy required by a living organism is a secondary matter. If it cannot be obtained by oxidation, other chemical reactions, although of a less efficient kind, are made use of."

If this is the case, it is easy to understand how the large number of animals that can live without oxygen obtain their energy—they simply use more food and discard it at the point at which oxidation begins in the aerobic animals.

VALUE OF THESE FACTS TO THE PHYSICIAN.

These facts are of much importance to the practicing physician. He is required to solve numerous problems which call for the selection of food of the right *physiologic value* for a given individual. What may be the right physiologic value for one may not be suitable for another. It is possible that the difficulty lies in a perversion of anaerobic metabolism in one case and aerobic metabolism in another. It has been conclusively shown that in practice the caloric value of a food is no strict indication of its nutritive value, but it has not been shown why this is so. With the recognition of the fact that an animal body is not merely a furnace in which food is burned, but that a long series of chemical changes in the food takes place, it is not difficult to see why practical results often cannot be obtained with foods valued only by their oxidation properties. To quote Bayliss again:

"The general conclusion seems to be justified that the cell mechanisms are such as to be able to use chemical energy whether it comes from oxidation or otherwise, and that they are independent of the particular chemical reaction which affords it."

The animal body is highly complex, with a metabolism that is in part anaerobic and in part aerobic, as some tissues live by the former process and others by the latter.

SUMMARY.

Heat or energy may be produced by chemical cleavage as well as by oxidation. Heat may be a degradation of energy, and in the human organism it is an excretion. Heat measurement alone is not a safe guide for the calculation of food values. This is especially true at the beginning of life when growth is the all-important factor. The foods that *build* rather than those that readily undergo oxidation must be properly gaged if we are to have healthy development. Some form of biologic testing of foods must be elaborated if an always reliable gage of nutrition is to be established.

[3] Von Bunge, Gustave: Text-Book of Physiological and Pathological Chemistry, Philadelphia, P. Blakiston's Son & Co., 1902.

THE REGENERATION OF USED LUBRICATING OIL.

IT was long considered impossible to regenerate lubricating oils because it was believed that they had undergone a necessary loss of lubricating power in the course of their employment. This has now been proved not to be the fact. The French scientist, M. Riallaud, has just investigated a physico-chemical process which gives excellent results. As described in the July-August number of *Les Annales des Falsifications et des Fraudes*, the process is as follows:

Used lubricating oil contains three kinds of impurities:

1. Very minute metallic particles, the smallest of which may have only 1/3 of a micron for their largest dimension;

2. Particles of carbon of about the same size as the foregoing, these being especially frequent in the oils coming from explosion motors;

3. True metallic soaps result from the combination of the metals and the fatty acids proceeding from the original lubricants when the latter are of organic origin, like castor oil. In the case of mineral oils compounds analogous to the naphthenes appear to be formed. These two kinds of compounds, which are very unstable, are readily decomposed by heat, and when thus decomposed they deposit upon all heated points metal oxides which possess abrasive properties similar to those of carbon particles.

These particles of carbon or metal are visible under the microscope and they impart to the alloys in which they are found either some coloration or a certain degree of turbidity; the metallic compounds may, however, be found in an oil which is perfectly clear.

No purely physical process is capable of completely removing these impurities since the first set of particles are too small while the second are soluble. M. Riallaud has recourse, therefore, to a veritable "sizing" analogous to that of wine and beer. Two aqueous liquids are prepared, one of which consists of dilute sulphuric acid, while the other contains caustic soda, tannate of soda and gelatine, the latter being obtained from tannate of soda by means of a large excess of soda lye. This excess and the concentration of the first liquid must be such that upon mixing together equal volumes of the two liquids the mixture will continue to remain acid. Under these conditions sulphate of soda will be formed, while the tannin combines with the gelatine to form a mucilagenous precipitate.

After heating the oil to be regenerated in order to render it more fluid, about 5 per cent of its own volume of the first liquid is added—this volume being dependent upon the degree of concentration and the content of impurities; the mixture is then vigorously stirred, whereupon the naphthenes and the fatty acids of the metallic compounds are set free; there will be formed the sulphates of the metals which they contain and which remain in the aqueous solution. An equal volume of the second liquid is then immediately added, the stirring being continued vigorously, thereupon the aforesaid combination of the tannin and the gelatine will take place. This mucilagenous precipitate carries down with it the minute particles of metal and of carbon, and even portions of the sulphates produced, especially of the sulphate of soda. The density of the gelatinous particles thus formed is so great that density of the gelatinous particles thus formed is so great that upon decantation they are rapidly separated from the liquid.

The mixture is decanted while hot and then filtered, still while hot, in order to separate such particles as have not been deposited by the decantation. The regenerated product is found to possess the same qualities as the original oil with the exception merely that the index of saponification of vegetable oils is somewhat diminished.

FIG. 1. THE JACKSHAFT BEING LOWERED INTO PLACE IN THE PROPELLER-TESTING PLANT

Propeller Testing Laboratory at McCook Field*

An Elaborate Plant of the Army Air Service

By F. W. Caldwell, Aeronautical Engineer, Air Service, U. S. Army

THE Army Air Service has put into operation at McCook field a propeller testing laboratory that is believed to be the most powerful and complete plant of its kind in the world. The existence of this laboratory and the scope and character of the work done there are almost unknown among aeronautical engineers and others interested in the aeronautical industry. This is primarily due to the necessary conservatism which has governed in making public military activities during the war.

The purpose of this article is to give a description of the laboratory equipment and of the scope of the tests that are carried out there.

This plant was erected in order to safeguard the experimental propellers against the possibility of failure in the air and at the same time to make tests of promising inventions and designs.

Serious propeller failures have been so rare with the Army during the last two years that many persons do not realize the damage that is usually caused by them. The fact that these accidents have been so rare is largely due to the policy of not allowing any propeller to go into the production until the design has been standardized. This process always includes a destructive whirling test of at least one propeller of the design made of the wood which is proposed for production. The test given is an overload test, the amount of overload and the endurance of the test being varied at the discretion of the engineering department; for most wooden propellers, however, a test of ten hours at an overload of 50% is sufficient to insure an ample factor of safety.

Anyone who has seen the results of a bad propeller failure need not be told of the effect. It is only necessary to imagine an unbalanced centrifugal force of 30,000 lbs. resulting from the loss of one of the blades; with this centrifugal load changing its direction with each revolution it is only a matter of good fortune if the whole machine is not wrecked.

*Reprinted from the *Aerial Age Weekly*.

In designing this testing laboratory a number of sources of power were considered. At the start we laid down the following specifications for the design: (1) the plant must be capable of developing a maximum power of not less than 2,200 horse-power; (2) it must be provided with an accurate speed control up to the maximum speed of 3,000 r.p.m.; (3) provision must be made for accurately weighing the thrust and torque; (4) a bombproof must be provided for catching the flying parts of broken propellers and the bombproof and the base of the power plant must be arranged in such a way as to minimize the interference with the flow of air through the propeller; (5) provision must be made for an observation chamber protected from the flying parts; (6) suitable equipment must be provided for measuring the deflection of the propeller while it is turning.

A number of different ways of furnishing the power for the operation of the propeller shaft were investigated. The steam turbine offered the objection that a large steam boiler equipment was required and the horse power delivered could be only approximately estimated from the bowl pressure. The alternating current electric motor did not offer satisfactory speed control. No standard type D. C. electric motor of this power and speed could be located and we were assured that considerable trouble with commutation would be encountered with a direct current motor of such high speed. Direct current motors of lower speed were available and estimates were obtained on gearing to step the speed up. The time required for delivery was considered impractical.

Meanwhile it was found that a number of Sprague dynamometers rated at 200 to 300 horse-power were available. These can be run at 200 horse-power continuously if proper cooling is provided, and can be run for a few minutes at 300 horsepower.

The Sprague machines offered all the advantages of great speed range, accurate control, and accuracy of power measurements. Furthermore, the Sprague machines, being of

FIG. 2. THE FOUR SPRAGUE TESTING DYNAMOMETERS

smaller diameter, could be streamlined in such a way as to interfere as little as possible with the propeller blast. It was found that sufficient power could be obtained by the use of four of these machines in a row.

The arrangement of the four Sprague machines can be seen in Fig. 2. This photograph, taken during the course of construction, shows the concrete supports for the motors and the framework of the concrete housing. At the right hand end of the picture is shown the massive foundation of the jackshaft pedestals. The motors are joined by Francke couplings of ample size. These couplings have given no trouble whatever.

Figure 1 shows the jackshaft being lowered into place. This jackshaft is a six-inch nickel steel shaft. This size and material have been found necessary to withstand the shocks imposed by a suddenly breaking propeller. To further reduce the shock a shaft extension is provided. This extension is bolted on the shaft end by means of four ⅝-inch bolts. These bolts are drilled out inside to 5/16 inch. If a propeller breaks near the hub on one blade the unbalanced centrifugal force breaks the bolts and the shaft is not injured.

The archlike bombproof shown in Fig. 1 is being used as a crane. It is provided with wheels and a track and serves to move any of the motors or parts when required. The manner in which it serves as a bombproof is more apparent in Fig. 3. In this figure also may be seen the observation slots which lead down to the observation chamber. In order to avoid the possibility of broken particles flying through these slots into the observing room, observations are always taken on the side of the axis where the propeller blades are moving upward. On the other side the slots are covered with a piece of boiler plate.

As the bits of broken propellers fly out almost exactly in the plane of revolution it was not found necessary to make the bombproof very wide. At the right of the picture in Fig. 1 can be seen the brick power house. This contains the motor generator set which furnishes direct current and contains a small shop for adapting experimental propellers for testing as well as an office for the engineer in charge of the testing plant. A thorough description of each test is kept here and it is possible to refer to any past test and find photographs and all details of the test.

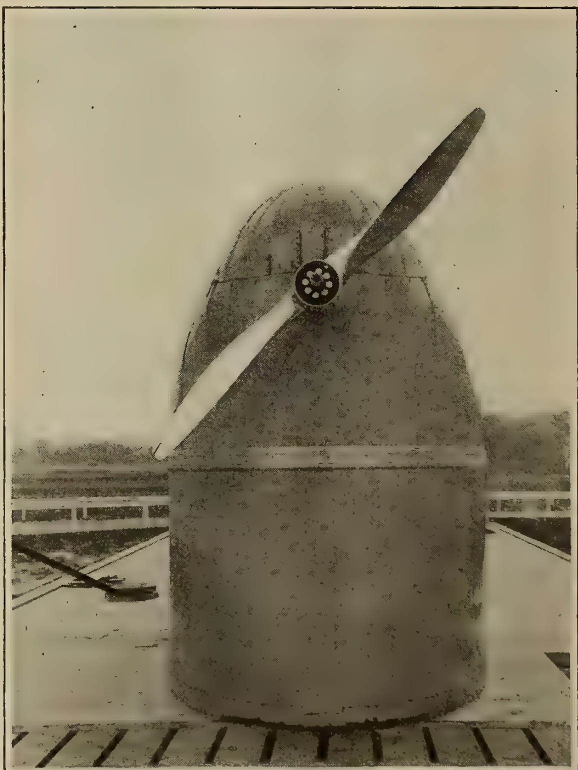


FIG. 3. PROPELLER TEST RIG SHOWING A PROPELLER IN POSITION FOR TEST. NOTE THE OBSERVATION SLOTS IN THE FLOOR BELOW THE PROPELLER

The 1,000 K. W. motor generator set is used which is a standard Westinghouse equipment. The size of this machine is ample and the power is great enough to provide for any probable future requirements in the way of increased size of the testing motors. At the rear of this machine are the contactors through which the power input to the Sprague motors is regulated. These contactors are operated by means of remote controls which are located in the observation chamber underneath the propeller shaft. Alternating current is furnished by a local power company at 6600 volts. The normal voltage of the D. C. generator is 550, but the voltage is varied according to the speed at which it is desired to turn the Sprague motors, as this method is economical of power and the current from the generator is not used for the operation of any other machines.

Returning to the description of the testing plant proper a drawing of the principal members is shown in Fig. 4. The flexible couplings between the motors are the well-known Francke couplings, and, being of ample size, they have never required any attenion since they were installed.

The floating coupling between the motors and the propeller shaft acts as a flexible coupling and at the same time must allow the propeller shaft to move axially ¾ inch in either direction without transmitting any thrust to the motor shaft. This requirement

was so unusual that a new type of coupling had to be designed. The original design gave a little trouble in eliminating all of the thrust; a later design, however, appears to give very satisfactory results.

The scale mechanism was designed and built by the Toledo Scale Co.

The torque is applied to torque bellcranks (Fig. 4) by means of short links. The torque bellcranks are all tied together by means of horizontal links so that the total load from all the machine is applied to the bellcrank nearest the scales. Here an ingenious device maintains tension in the vertical torque scale rod shown under the floating coupling no matter which way the motors are turning.

The thrust bearing is a standard Kingsbury bearing and need not be described here. The thrust is transmitted to a bellcrank and again to a vertical scale rod which is maintained in tension regardless of the direction of the thrust.

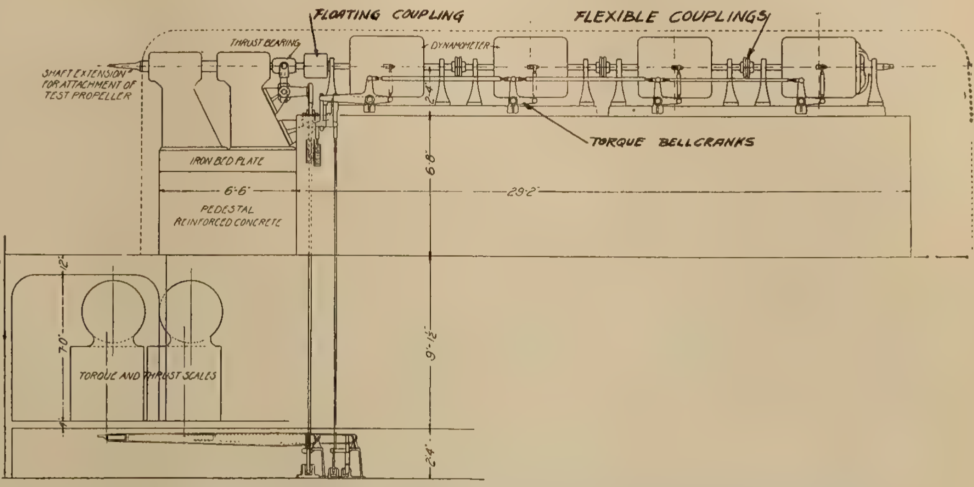


FIG. 4. PRINCIPAL MEMBERS AND DIMENSIONS OF THE DYNAMOMETER WITH TORQUE AND THRUST RECORDING SYSTEM

The observation chamber is located directly underneath the propeller shaft and both torque and thrust scales are located in this room. The scales proper are of the indicating type and are shown in Fig. 6. Each scale has a total capacity of 6,000 pounds, the dials being graduated to show 2,000 pounds for one complete turn.

Between the two scales and at the top is an electric tachometer (Fig. 6) which is used to adjust the revolutions approximately. Exact revolution speed is obtained by means of an ingenious electrical counting device designed by one of the testing staff, Mr. Gray.

At the right of the picture (Fig. 6) is the control panel for the Sprague motors. The motors are operated in two parallel sets, each set comprising two motors in series. The two control handles are arranged to permit operation of the two sets either independently or together. The ammeter near the top of the panel shows the current of each set and it serves as a very convenient means for balancing the load.

Just above the scales may be seen the observation slots in the roof of the room. These slots are in the plane of revolution of the propeller and extend all the way across the room. By close inspection of Fig. 5 these slots may be seen at the extreme top edge. At the time this picture was taken all of the slots had been provided with felt-lined trap doors in order to minimize the noise in the room. Any of these doors may be opened when an observation is to be made and one of the doors is shown held open in the picture.

The transit telescope shown here serves to give accurate readings of the axial deflection of the propeller blade at any radius. The telescope is provided with a mirror set at 45 degrees so that the revolving propeller may be seen through the slot by looking into the telescope.

The sliding ways on which the telescope is mounted are set up exactly parellel to the axis of the propeller shaft. Thus the telescope is exactly parallel to the plane of revolution of any radial element of the propeller. When the propeller is turning over at idling speed the telescope is adjusted until the cross hair is exactly in the plane of revolution of,

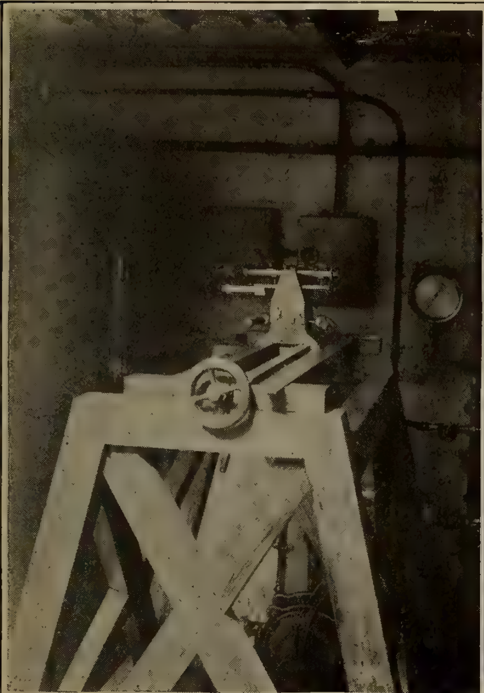


FIG. 5. TRANSIT TELESCOPE AND MIRROR FOR OBSERVING DEFLECTIONS OF PROPELLER SPEED

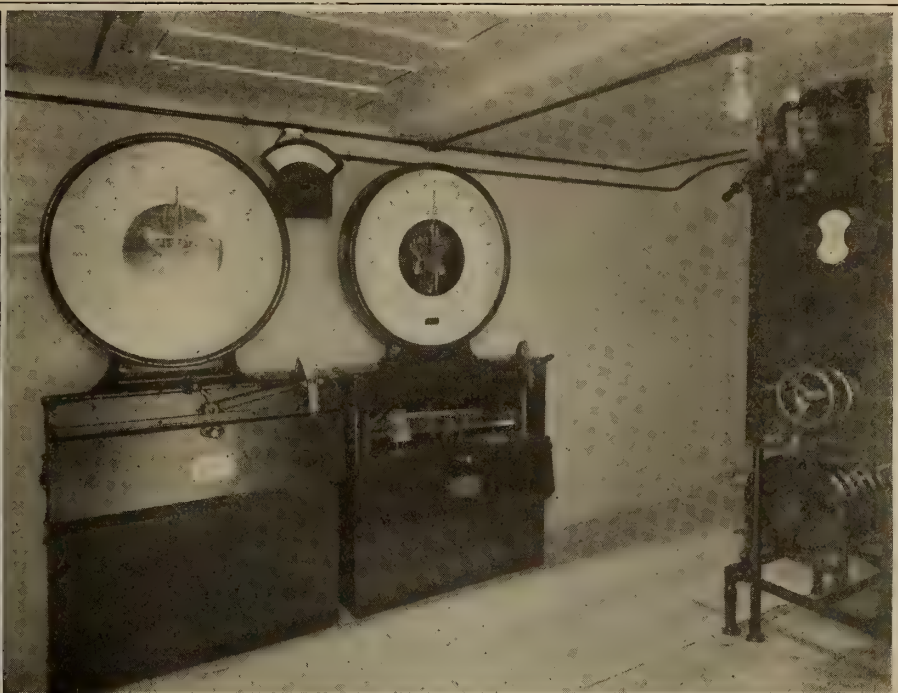


FIG. 6. TORQUE AND THRUST DIALS IN UNDERGROUND OBSERVATION ROOM WITH DYNAMOMETER CONTROL SWITCHBOARD

say, the leading edge. The position of the telescope is then noted on the scale at the right. When the speed is increased, the telescope is again adjusted and the position again noted. The difference of the scale readings gives the axial deflection. This value is subject to a correction due to movement of

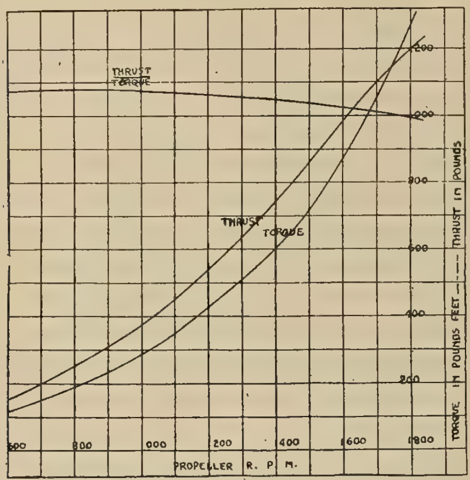


FIG. 7. CHARACTERISTICS OF TYPICAL PROPELLER FROM McCOOK FIELD WHIRLING TEST

the shaft which has to be measured separately and subtracted.

By measuring the axial deflection of the leading edge and the trailing edge of a propeller at any point the change in pitch may be obtained by the method shown in Fig. 10.

The present method of measurement gives the average deflection of the two blades. A stroboscopic method is being

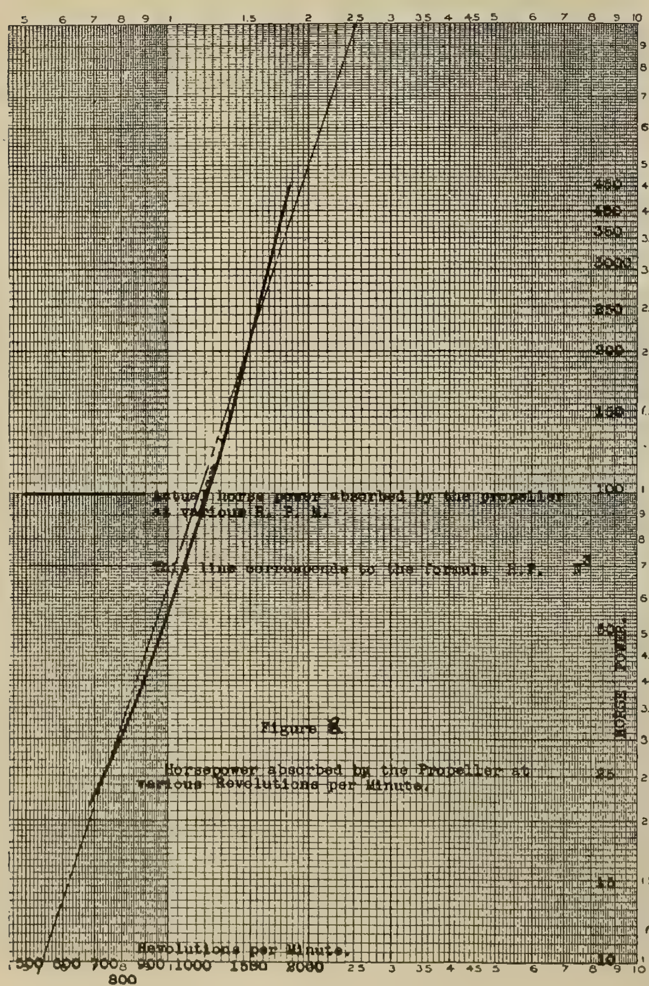


FIG. 8. CURVE SHOWING THE HORSEPOWER OF A PROPELLER AT VARIOUS R. P. M.

worked out to give the measurements on the two blades separately.

Another test which is of great practical value is the water spray test. Two views of a water spray test are given in Figs. 12 and 13. It will be noted from these that the water is supplied from an overhead pipe at the top of the bombproof. These tests may be made as severe as desired by regulating the amount of water, the speed of the propeller, and the length of the test.

A typical curve of thrust and torque of a propeller as obtained from this rig is shown in Fig. 7.

If the thrust of the propeller were proportional to the square of the R. P. M. and the torque of the propeller were also proportional to the square of the R. P. M., then the ratio of thrust or torque would be a constant. Since the ratio of thrust to torque is theoretically independent of R. P. M., it is considered a good criterion of the value of a propeller as a thrust producer under given conditions.

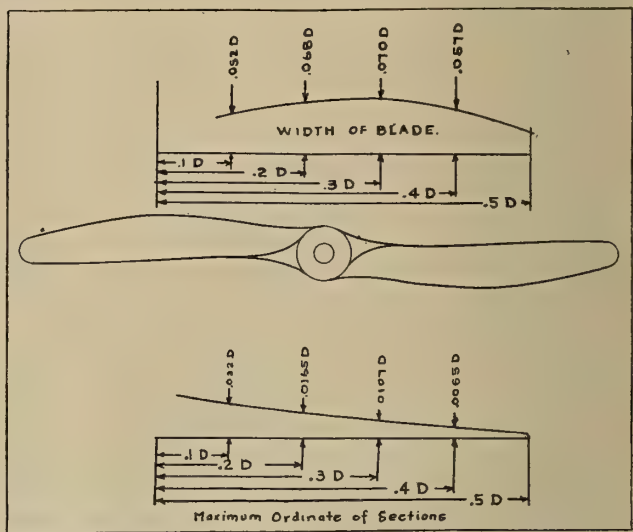


FIG. 9. GENERAL SHAPE OF PROPELLER USED IN TYPICAL TEST

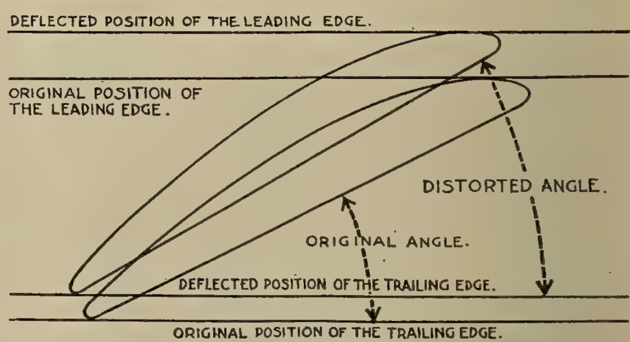


FIG. 10. OBTAINING THE CHANGE IN PITCH

By reference to Fig. 7, however, it may be seen that the ratio of thrust to torque decreases after the speed of 1,000 R. P. M. is reached. This corresponds to a top speed of about 320 miles per hour. This speed probably corresponds to the critical speed for the aerofoil at the extreme tip when working at the corresponding angle of attack. As the velocity is increased the critical speeds of sections nearer the hub are progressively obtained, so that there is considerable lowering of the thrust torque ratio when the speed of 1,800 R. P. M. is reached. (For explanation of the critical speed of propeller aerofoils, see Article by F. W. Caldwell and E. N. Fales in "Automotive Industries" for August 28, 1919.)

A curve showing the horse-power of the propeller at various R. P. M. is drawn in on logarithmic paper in Fig. 8. Adjacent to this curve is drawn a line representing what the curve would have been if the power were proportioned to the cube

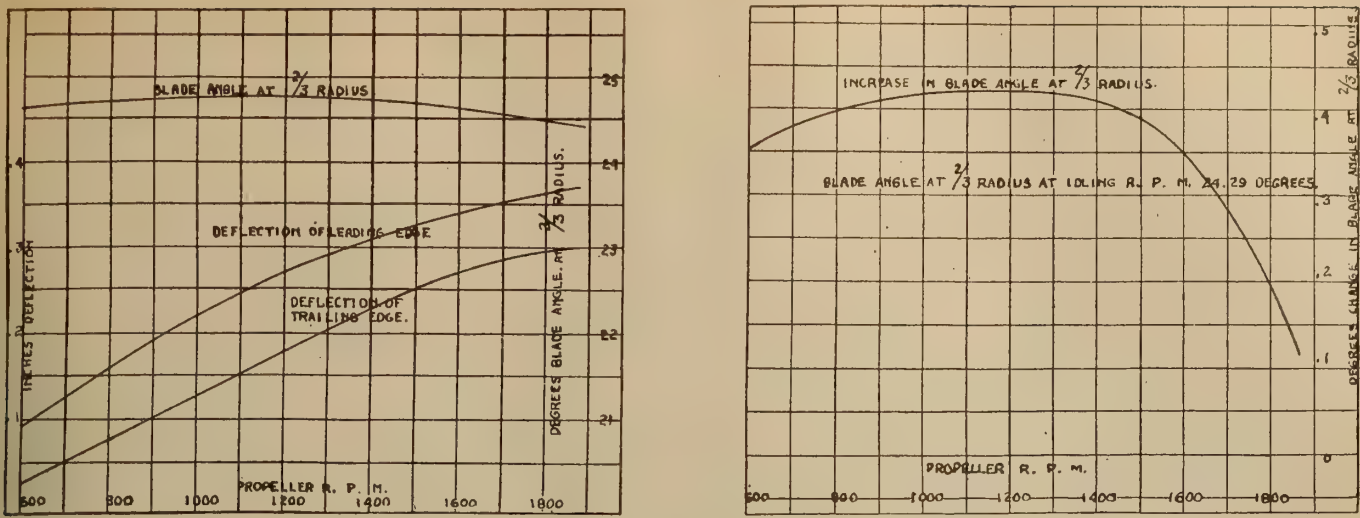


FIG. 11. CHARACTERISTICS OF TYPICAL PROPELLERS FROM McCOOK FIELD WHIRLING TEST

of the R. P. M. It will be noted that the horse-power is not proportional to the cube of the R. P. M.. In view of our present knowledge of propeller aerofoils, it is not to be expected that the horsepower would be proportional to the cube of the R. P. M.

A typical set of deflection readings for a propeller is shown in Fig. 11. Reference to the curve showing the blade angle at various R. P. M. shows that the angle first increases and then decreases as the propeller is speeded up. This is shown in a more pronounced manner in Fig. 12, where the change in blade angle, referred to the original angle, is plotted against R. P. M. We have assumed that the change from an increasing to a decreasing blade angle is the result of a shift in the center of pressure of the aerofoils.

The change in angle of the propeller in motion offers some very valuable data to the designer. While the distortion at a fixed point undoubtedly differs considerably from the amount of distortion encountered in flight, experiments on a series of different blade shapes have enabled us to draw some important conclusions as to the effect of different blade shapes on the distortion. The results have been particularly useful in connection with the stress analysis of propellers.

The actual destructive tests have covered a very wide field. Tests have been made on various types of propellers, such as automatically variable pitch propellers, adjustable pitch propellers, propellers made of steel, composition propellers, various designs of wooden propellers, and various methods of constructing wooden propellers from conventional designs.

In an article of this kind it is obviously impossible to cover with any degree of detail the ground of the experiments which have been carried on. It may be said, however, that about two hundred and fifty tests have been made on this plant for the Army and Navy, and that propeller failures in service have been reduced to an extremely small number. At least two inventions, the Micarta Bakelite propeller and the variable pitch propeller, have been developed to a point where they bid fair to become important factors in the aeronautical industry.

ELECTRIC TRUCK WITH REGENERATIVE BRAKING.

Dr. Charles P. Steinmetz has recently announced the development, after a number of years of research, of a light weight electric truck, one of the principal features of which is the method of motor control giving the motor compound characteristics by a storage cell floating on the field circuit.

The result of this method of control is speed maintenance, quick starting, power saving in the beld at large currents and the feature of regeneration both on down grades and on stopping.

The field and armature of the motor revolve in opposite directions, each driving one of the car wheels. In this way motor weight is saved, the differential is eliminated, and the truck is as a result simpler and more compact.

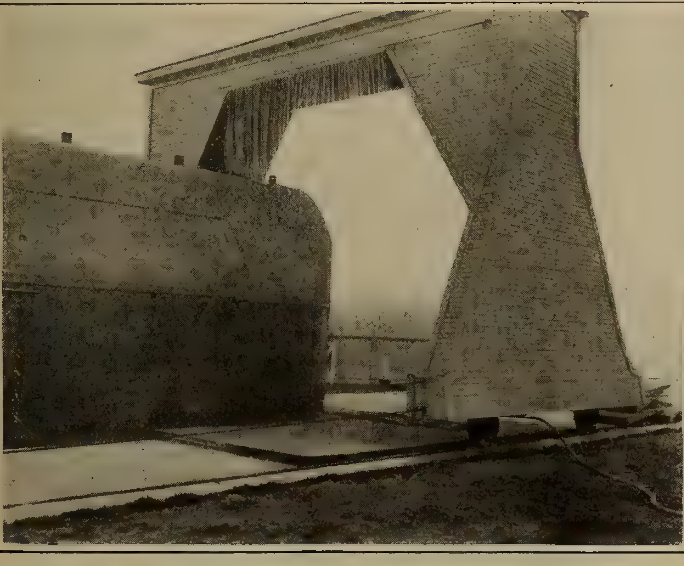


FIG. 12. VIEW OF PROPELLER UNDERGOING WATER SPRAY TEST LOOKING DOWN STREAM

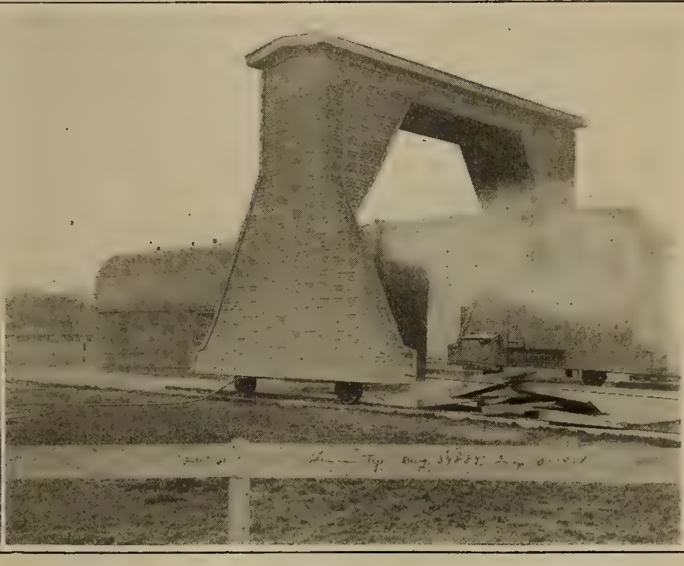


FIG. 13. VIEW OF PROPELLER UNDERGOING WATER SPRAY TEST LOOKING UP STREAM

Invention in Aeronautics*

Is America Going to Attain Commercial Supremacy in the Air?

By Frederick W. Barker

As the nobler sensibilities of mankind have always found expression in words of upward import, and human constructive unrest has employed those language terms which pertain to things and conditions above the earth, it is only natural that inventive endeavor through the ages should have been so largely directed toward solving the problem of flight by man, to which the final touch that changed probability to success was given by the Wright brothers in 1903.

I recall to you the wondrously poetic and masterly review by the Honorable James M. Beck, given before the Aeronautical Society of America on the decennial anniversary of the Wright's success, in which the struggles of inventors through the centuries to conquer the air were described in silver-tongued oratory. This address will I know always be fresh in the minds of our members and needs no traversing.

In our almost immediate times it was Sir Hiram Maxim, brother of a past president of the society, Professor Langley and Octave Chanute who contributed some of the real pioneer work which enabled the Wrights to take their power glider into the air and to control it laterally against falling.

The principles of lift and drift for sustentation of an aerofoil were appreciated and applied before the practical demonstration in 1903 of compensating means for variable pressures which gained the victory and discovered to the world mechanical means for maintaining the stability of a flying machine.

Here then was born the invention of the airplane, involving actual, competent material for a basic patent. Basic in the sense that the principle of balance control was first demonstrated. The means employed—flexible wing portions to be warped in a helicoidal fashion—were not ideal, but they were practical and they served the purpose.

The Wright patent has been the subject of too much discussion by patent experts, and its sustainment by the Appellate Court has apparently so completely closed all controversy that more than mere comment would be out of place.

The particular point in the Wright patent that has always appeared puzzling is, why the broadest claim in the patent was couched in the restricted language employed. The claim reads like this:

"In a flying machine, an airplane having substantially the form of a normally flat rectangle elongated transversely to the line of flight, in combination with means for imparting to the lateral margins of said airplane a movement about an axis lying in the body of the airplane perpendicular to said lateral margins, and thereby moving said lateral margin into different angular relations to the normal plane of the airplane."

The method of expressing the idea of varying the wing surfaces for lateral control could have been better expressed as follows:

"In an airplane, a supporting aerofoil, and movable portions arranged at opposite sides thereof to respectively increase and diminish pressure resistance, for lateral balance."

Then the claim would have been in better shape for judicial endorsement, which the splendor of the Wright brothers' achievement warranted, without requiring to lean upon sympathetic consideration of the court, which to my mind was the determining factor in its favor.

As matters stand however the Wright patent is the foundation patent in the art of aviation with respect to movable wing portions of ailerons, and there is nothing to prevent the present owners of the Wright patent from enjoining other unlicensed users of this balancing feature.

The Wright patent does not cover *any* means of compensating for variable side pressures, and there are not wanting other inventors who have sought and are seeking to devise different means for enabling an airplane to fly with lateral balance. The art is necessarily enriched by such attempts of a more or less practical character.

Since the heavier-than-air machine, as thus far evolved, comprises a supporting aerofoil, longitudinal and lateral control ailerons, and a directional rudder, development will be mainly through refinement of these elements, and in the creation and refinement of the thousand and one accessorial devices which naturally result from intensive work and study.

Other types of flying machines, such as the helicopter and ornithopter still in the womb of invention's laboratory, cannot receive the assistance of engineering ability until they at least assume the condition of fledgelings, to offer some basis for scientific development. But the airplane has today a recognized structure composed of coördinated elements which interact to supply all the necessary functions for controlled flight.

A new art is thus born into the world, having vast potentialities for expansion, now occupying the minds of inventors in all civilized lands, whose interests will grow with each unfolding feature until aviation becomes actually an exact science that shall place its protective mantle over the greatest industry that has ever been known.

America, following her brilliant initiative in blazing the way for flight by man, fell behind other nations in progressive work, while England, France and Italy produced advanced examples of flying machines—though these have been mainly of military types. But the native inventive genius of Americans is again coming to the fore, and it is certain that the next few years will show the most radical improvements to be of American origin.

This therefore seems to be an opportune time to offer a suggestion or two to aeronautical engineers and others as to the part patentable invention is bound to have in bringing about a perfected state of aviation.

From time immemorial we have had vessels that could float on water because the density of that medium permits buoyancy, and the air also was found to give buoyant support since the days of the hot air balloon; but the real conquest of the air came only when a controlled airplane was caused through speed of its movement to pack the air before it sufficiently to convert the tenuous atmosphere into a weight sustaining medium. Even as the child first learns to walk totteringly upright, and gradually with the aid of his intelligence, under practice and with increasing strength, walks firmly and then can run, all with perfect assurance and grace, so will man improve his new winged vehicle to the extent that it will eventually satisfy all his needs of aerial navigation.

Of course it is the internal combustion motor which rendered possible the flying machine, and we have to thank the automobile industry and the engineering profession for the numerous refining influences they brought to the motor and thus gave the airplane its opportunity to come into being. But it must not be overlooked that the automobile motor has also proven the most serious handicap that aviation has had, simply for the reason that we have sought to apply to a new, more arduous duty an instrument that had been perfected along lines suited only to an older and less difficult task.

Invention has still its most important field in the production of a thoroughly reliable aviation power plant, and this will come through designs providing sturdy construction wherein the weight is kept within bounds, with more efficient temperature control, continuous and thorough lubrica-

*Read before the Aeronautical Society of America, January 20, 1920.

tion, an ignition system that can be absolutely depended upon, and propelling means that will develop a maximum of thrust. Patents which improve these and allied features to help the power plant in the delivery of continuous high power output over an extended period will do more than anything else to advance the cause of commercial aviation. This progress will be gradual and tested out at every step. But inventors and aeronautical engineers must get completely away from the intermittent and low duty form of motor which is good enough for the automobile, and strive to meet the sterner conditions of a flight sustaining power plant.

The scope for inventive ingenuity in this field alone is so vast and the reward for success in every detail so sure and generous that its attraction is irresistible and will be responsible in the next few years for innovations which will easily differentiate the aviation motor from the automobile motor.

Invention also will show the way to take off an airplane without a starting run over the surface, and to alight and stop wherever desired. The natural forces to serve these ends are available, and even now are in process of harnessing.

Here and there will stand out some bold concept whose deviser may achieve more fame and receive greater emolument than others, but ancillary devices, marking various stages of development, will result as the contribution of many inventors who attack the problem involved from different points of view.

There was published recently in the Journal of the Patent Office Society a report by J. H. Colwell, one of the principal examiners in the Patent Office, of the more important subjects treated of by inventors, and this report, in so far as it relates to aeronautics, is so succinct and comprehensive that I am introducing Mr. Colwell's account in this paper. It reads thus:

"The importance and the application of heavier-than-air craft to military purposes is obvious and self-evident.

"The attention of the country immediately centered on this new form of vehicle, and it was natural that the minds of experts and inventors were directed to improvements in and devising new forms of aeroplanes, as well as to numerous related auxiliary devices, with the result that the Patent Office was flooded with applications bearing on aeronautical devices.

"There is believed to be no exaggeration in asserting that the advance in the development of heavier-than-air craft made during the past five years would have taken from fifteen to twenty years under normal circumstances; 'Necessity is the mother of invention.'

"In so far as the development of a practical machine is reflected in the Patent Office, no new principle or mode of air-sustained flight appears to have been evolved. The aeroplane of the present day is based on the same principle and involves the general structure as first employed by the Wright brothers in their successful air flight in the first decade of this century. Notwithstanding this, however, there is a wide gap between the air craft of today and that of 1914 as regards the general efficiency, inherent stability, carrying capacity, motive power, controls and radius of action, as well as in various accessories, including instructional and training devices.

"The improvements show a general tendency to widen the range of use by anticipating larger load carrying capacity, necessitating increased engine power, and improved motor construction. Different types of modern planes are now equipped with engines ranging up to over 1,200 h.p., including multiple engine units with reserve power.

"There is no reason to suppose that the limit has been reached, but, on the contrary, the air navigation is still in its infancy.

"Increased power calls for increased strength in frame construction without too great a sacrifice of lightness, as weight is a vital factor. This brought to the fore forms of bracing, struts and trussed wing beams. To overcome excessive wind resistance of exposed parts, which cause a useless waste of power and speed, attention was turned to fairing and stream-lining all such parts, as struts, spars, engine housings, fuel tanks and radiator casings, as well as landing carriage frames. As at high speeds comparatively small areas exert by their wind resistance a greater relative detrimental influence, stream-lining the guy and brace wires has even been resorted to.

"To secure increased strength with the necessary lightness, resort is had to hollow metal tubing, but more generally to various forms of laminated wood framing, as embodied in struts, wing beams and ribs, as well as the fuselage and pilot's car itself. With methods devised and means of uniting and arranging the grain of wood laminate, it is possible to construct a wing rib lighter than one of steel of the same strength. Various materials, as aluminum and other metals, and compressed and treated fibrous structures are constantly being devised, as substitutes for linen in the supporting wings, and also, various substances and compositions commonly termed 'dope,' for treating the wing surfaces.

The hulls and pontoons of hydro-aeroplanes and flying boats are constantly being increased in size and strengthened to make them more seaworthy in withstanding rough water, and the shock of alighting thereon. This has led to the creation of what might be considered a distinct branch in marine ship building, to some extent following the lines of the earlier hydroplane or speed boat. Increased strength necessitates the introduction of longitudinal and tansverse hull framing, providing bulkheads for ballast and other compartments, analogous to that in ship building with variations to resist special strains resulting from the peculiar demands.

"A system of aeroplane construction which is being developed and particularly adapted to large craft, appears on its face, not only interesting, but plausible and practical, provided the location of the weight is not detrimental. Broadly stated, the system comprises a hollow plane merged into the fusilage so that the large trussed wing spars, the engine housings and fuel tanks, as well as the pilot, are enclosed within the lifting surface itself. The center of the plane between the upper and lower walls is deep, while the wings taper to small depths towards the tips. The entire machine, including the pilot's car, is practically a part of the lighting surface, thereby necessitating comparatively few external wind resisting parts.

"Among other devices which are being continually received are detaching means for readily releasing bombs, mail bags and other articles, steering devices and automatic controls, wind pressure vanes for automatically regulating the speed, maintaining a constant angle of incidence and preventing the machine from being pointed dangerously upward, to exceed the critical angle and thus cause stalling, with a resulting fatal tail spin.

"Knock-down aeroplanes for ready transportation and assembling, telephone and telegraph accessories, and wind fans or mills for driving electric generators, and air and fuel pumps have received considerable attention.

"The merits of a heavier-than-air craft capable of hovering in the air, or stopping in flight, and also of descending and rising vertically have been fully appreciated, both for military and other purposes. The advantages of such a machine are obvious; among them is the necessity of only a limited or small area of ground space for landing and launching. Numbers of machines designed to possess these qualifications have appeared, the most common type being the helicopter or horizontally rotating screw propeller for exerting thrust. Some of these have no lifting plane, relying solely on the helicopter thrust, while others propose to use the helicopter in conjunction with the ordinary aeroplane, and so to arrange the power transmission that the tractor or pusher propellers can be cut out and power applied to the helicopter, or both operated simultaneously.

"Although it appears that, as yet, no practical and successful machine of the above type has been evolved, it is by no

means improbable that this problem will be solved in the near future, in view of what has been accomplished and the great strides in development along these lines by keen minded men of mechanical experience.

"In view of the constantly increasing altitude being reached in air navigation, numerous systems are being developed for obviating the ill effects of the highly rarified atmosphere, both on the pilot and in the functioning of the motor. These comprise various arrangements for compressing air, including wind fans, or motors otherwise operated. Some utilize the exhaust of the main engines for driving a turbo-compressor. By this means, a constant supply of air at uniform pressure is received, which is automatically regulated in accordance with elevation."

It will have been noted from the foregoing report that the sphere of invention has already widened out to an extent that admits the thoughtful endeavor of experts in many avenues of research, and proves that the inventive world is surrounding aeronautics with an association of arts, which, while each borrowing from one or more older arts, is itself of special character, and all of these new arts are interrelated through the science of aerodynamics, to whose dominant influence all aeronautical arts must be subservient.

The growth of the automotive industry in the past score of years to its present colossal proportions has undoubtedly robbed thoughtful persons of doubt concerning the possibilities before the flying machine, though still there are timid ones who prefer that others, and not they, should invest money in aviation enterprise, or that others, and not they, should venture to fly. Were all men so shortsighted there would be no progress, but that America does not lack boldness of spirit, alike in its captains of finance and in the masses of its people, to guarantee the adoption of aerial transportation, and the support of worthy aeronautical undertakings, is beyond question.

Though today, to the man in the street, there seems to be a lag in visible production of aircraft in America, that is only the surface view. The surest sign of the times is in the Patent Office, where inventions in the aeronautical arts already surpass in number those of many older arts. With invention rife, the meaning is that demand exists even though that demand is in as intangible form as invention itself. For invention springs from super-mentality, creating something new to satisfy an unprecedented condition.

Vision and courage only are needed in America to enable her to win commercial supremacy in the air—such vision and courage as the warring nations of Europe had in 1914 when they improvised, under fire, different types of aircraft for different military usages. True, expense was a minor consideration then, for the existence of nations was at stake. Now, America's honor is involved, for she is behind other nations in the production of up-to-date passenger and merchandize-carrying machines. This slumbering giant of potential productiveness must be pricked, and perhaps the golden guerdon dangled before it, to rouse it into its instinctive desire to out-distance all others.

The American inventor is doing his part in aeronautics, as he has ever done in other arts and sciences, enriching the world with new thoughts and ideas which need only application to crystallize into further development; and this is actually the epochal period when the judicious investment of money and business endeavor stand to realize the most glorious harvest that has ever been gleaned in industrial fields.

CONTROL AND MEASUREMENT OF ALTITUDE RECORDS.

It is of great importance that the performance of typical aeroplanes should be accurately known, and that methods of precision should be adopted for determining the actual path of a machine during a test flight. For this purpose Lieut. Robin writing in L'Aérophile of October, 1919, suggests the use of a barograph and a recording thermometer. An explanation is given of the method of reduction of the records, based upon the formula of Laplace, and an illustrative case is worked out.

The barograph is a very simple aneroid type. The pressure gauge consists of a series of thin cylindrical metal boxes, each of which has its base fixed to a spring beneath. Each box is exhausted, and its deformation under external pressure is limited by the spring, so that the deflections are proportional to the atmospheric pressure. A system of amplifying levers and a clockwork recording drum complete the outfit.

The thermometer is of the Fournier type. It consists of a cylindrical reservoir containing a small quantity of light, volatile liquor at its upper closed end. The remainder of the reservoir, together with a communication tube, and a flexible, crescent-shaped tube with one end fixed, are filled with a denser liquid. An amplifying device (and needle moving over a rotating drum) enables the movements of the free end of the flexible tube to be recorded. The movements registered are due to the expansion and contraction of the saturated vapor of the liquid at the top of the reservoir which acts as the thermometer bulb.—Abstracted by *The Technical Review.*

STEREOPHOTOGRAPHY FROM AN AEROPLANE.

OBSERVED from a sufficient altitude, the ground appears like a two-dimensional map, and nearly all plastic effects are lost. Stereophotographs, however, give us good ideas of level distribution, and, with the help of the stereo-comparator accurate measurement of height can in certain cases be obtained. These photographs are thus of the greatest utility for surveying purposes.

Several methods for obtaining stereophotographs are given by W. Klemperer, in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, October 15, 1919. The easiest way is to use two aeroplanes flying at the same height on the same course or on a parallel course. By photographing one aeroplane from the other on a special camera, the distance between the aeroplanes can be determined.

Besides this "distance" camera, both aeroplanes are equipped with a stereocamera proper, whose optic axis is suitably inclined. The inclination will depend on the focal length of the camera, the altitude of flight and the distance between the planes. This inclination will also settle the degree of plasticity obtained.

In the case of the aeroplanes steering a parallel course, the camera axis is inclined across the direction of flight so that a stretch of country lying midway between the two aeroplanes is photographed from two points of view. In case of the same course being steered, the leading machine has its camera inclined to the rear and the following machine to the front, so that the same stretch of country is again photographed from both machines. If only one aeroplane is available, two flights are required.—Abstracted by *The Technical Review.*

BOY MECHANICS FOR THE BRITISH AIR FORCE.

THE Air Ministry has recently instituted a new scheme to secure the entry of well-educated boys for training as skilled craftsmen.

Under this scheme, boys will be entered between the ages of 15 and 16 years for a period of ten years' color service in the Reserve. During the first three years they will undergo a course of educational and workshop training, graduating them to the rank of Leading Aircraftsmen in one or other of the skilled trades.

Those who show most promise during their training will be chosen for an additional six months' course of higher instruction, being promoted at once to the rank of Corporal. From among these, some may be selected for the grant of a commission, and will proceed to the Cadet College for training as flying officers.—Abstracted from *Aerial Age Weekly.*

FIG. 1. WHEEL WITHOUT TWIST OR WEATHER ANGLE WHICH WILL TURN IN THE BLAST OF AN ELECTRIC FAN

Paradoxical Windwheels and Soaring Birds

Rotary Thrust Produced Without Weather Angle

By Thomas O. Perry

THOSE who are familiar with windwheels know, or think they know, that the weather angle of the wings, or their inclination with the plane of motion, is a necessary feature for propulsion by the wind, and that the wheel must turn only in one direction according to the angle of weather.

In Fig. 2 are shown photographic prints of five small windwheels which, when held facing the breeze from an electric fan, were wind driven clockwise or anti-clockwise without any alteration either in construction, position or other conditions. Three of these wheels apparently turned one way as rapidly as in the reverse direction, the slight difference evidently being due to some rotation of the blast from the fan in the direction of fan revolution. This difference was eliminated when the blast was directed through a tunnel with thin longitudinal partitions. Our illustrations omit the tunnel which was used, but is not necessary except for refinement in exact tests.

Those who are skeptically inclined are advised to first try forms No. 1 and No. 2, as these two forms are very easily made and as easily managed. We have shown No. 1 with a wooden hub joining opposite wings separately attached, but the wings can as well be made of one piece of thin metal of uniform section from end to end without twist or weather angle throughout its length. Any kind of hub will do, and the exact curvature of the wings is not important. We made the camber about 1 in 14, width of wing 1¾ inches and length 10½ inches. The electric fan used was 12 inches in diameter, had a speed of 1,800 r.p.m. and was placed from 15 to 20 inches away from the windwheel. The average speed of the windwheel in either direction was about 1,390 r.p.m. This wheel had to be started by giving it an initiatory whirl with the fingers, though it would turn slowly of its own accord in a *direction contrary to the fan's motion*, in which respect this particular wheel was peculiar.

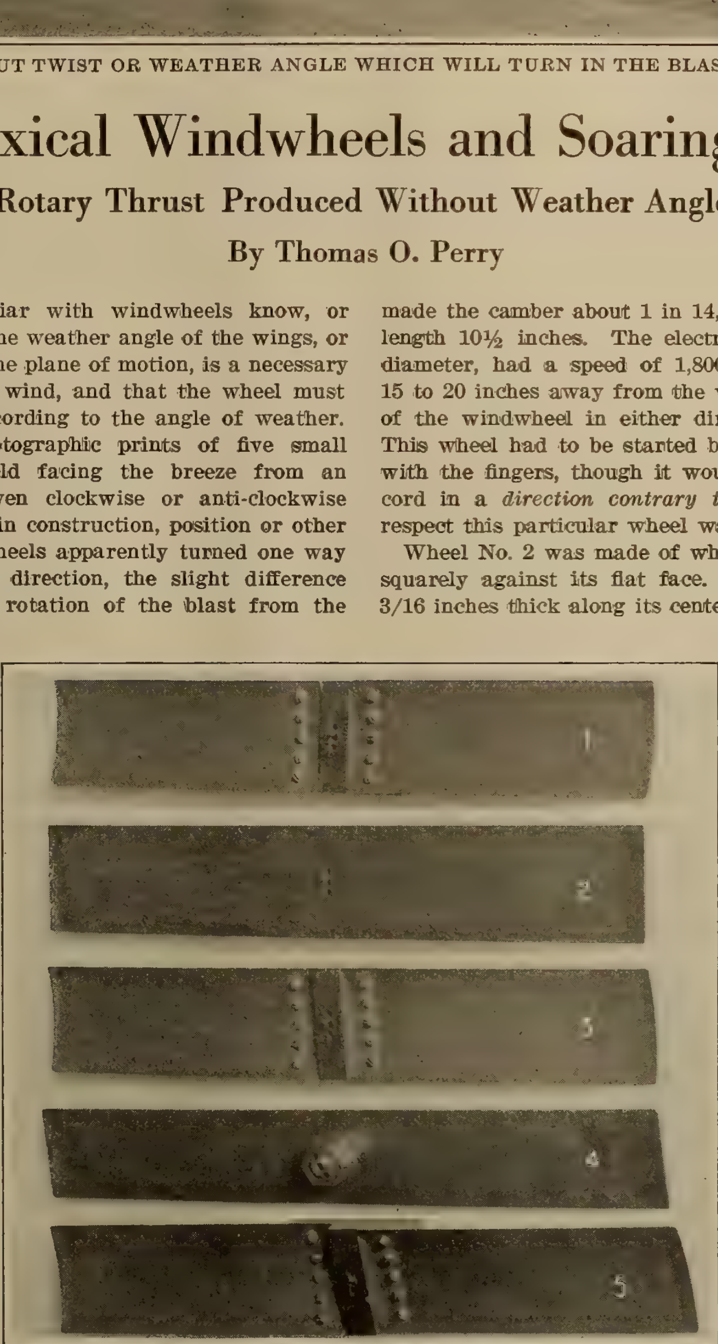


FIG. 2. WINDWHEELS USED IN THE TESTS

Wheel No. 2 was made of white pine and received the blast squarely against its flat face. The back was rounded from 3/16 inches thick along its center line to thin edges about 1/32 inch thick along the sides. To make this wheel it is only necessary to take a straight piece of wood 10½ inches long, 1¾ inches wide, 3/16 inch thick and round over one side from end to end. Any kind of hub will do, or no hub. This wheel is started very easily with the fingers and runs in either direction at about 1,650 r.p.m. On account of its lightness, the acceleration after starting is very rapid.

Wheels No. 1 and No. 2 responded so vigorously to the impulse of the wind after being started in either direction, that we were tempted to try another wheel made precisely like No. 1, except that the two wings were given a small weather angle of about 3 degrees after the manner of ordinary windwheels. This wheel, No.

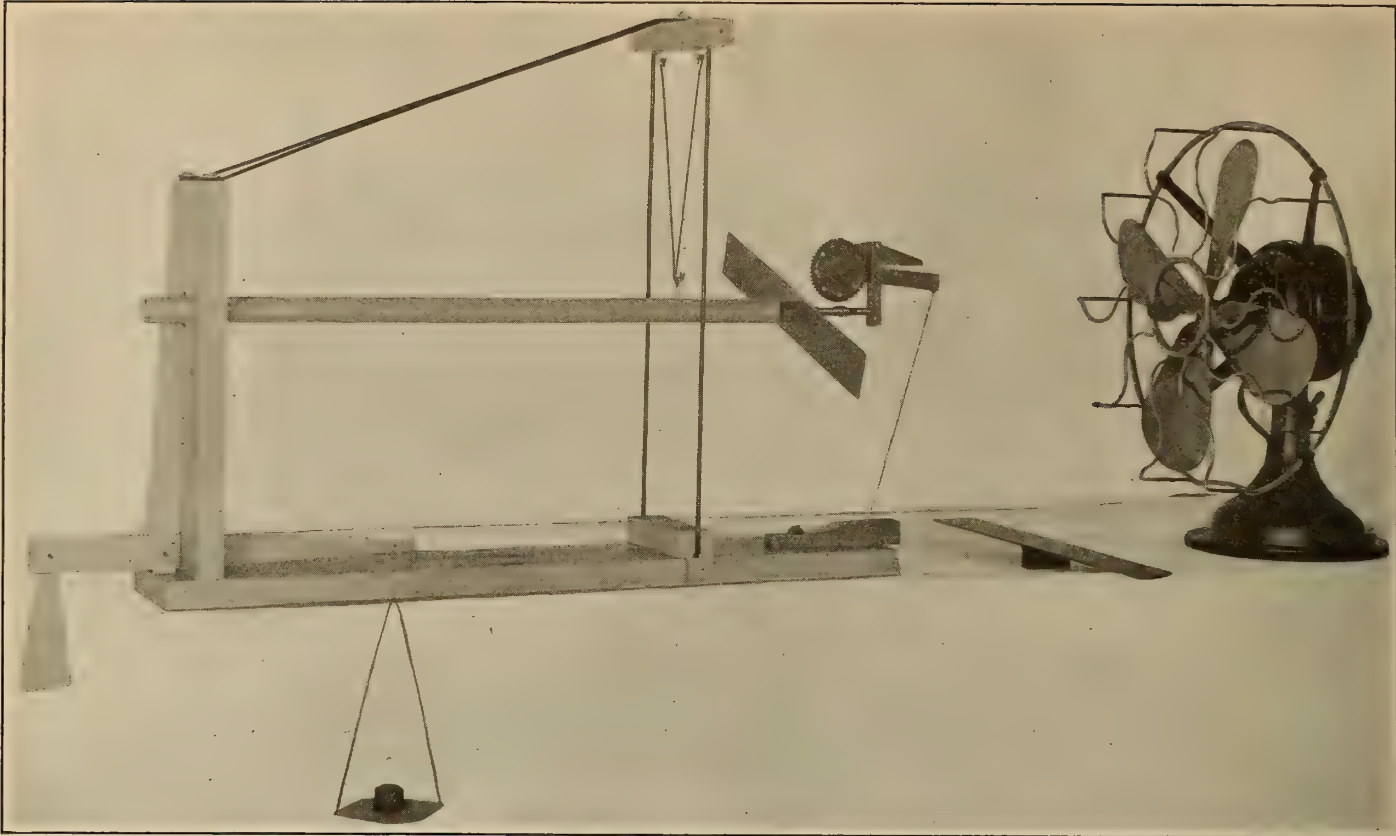


FIG. 3. APPARATUS FOR WEIGHING THE PRESSURE OF THE WIND IN AXIAL DIRECTION

3, would readily start itself and run in one direction just as any one would expect, making about 1,560 r.p.m. But, if given a vigorous push to start it in the opposite direction, it would run and maintain about 960 r.p.m. *against natural inclination.*

The fact that wheel No. 3 with considerable weather angle could be made to run backward against inclination, as well as the fact that wheels No. 1 and No. 2 ran equally well in either direction they were started, was at first supposed to be due entirely to the fact that these three wheels had at least one side made with transverse curvature. It was with the expectation of confirming this supposition that wheel No. 4 was made with both face planes parallel to each other. No. 4 was nothing more than a plain strip of hard and smooth sheet brass about 1/16 of an inch thick, 1½ inches wide and 10½ inches long fitted with a small hub at the center. Contrary to expectation, this wheel, too, maintained a speed of 1,030 r.p.m. after receiving a good start in either direction. It had to be started at much higher speed than any of the others by winding a string around the hub. It also had to be nicely balanced. Slightly rounding the sharp corners of the edges improved its performance.

Wheel No. 5 was the same as No. 3 except that the weather angle was increased to 8°, making it correspond more closely to the angle of ordinary windwheels. This wheel would not run backwards, and behaved according to expectation except in one particular. It made about 1,860 r.p.m. in a left-hand direction. Wheel No. 6 was the same as No. 5 in all reversed. It ran at about the same speed when used with the tunnel, always running in a right-hand direction. These two wheels would make about 690 r.p.m. with their convex surfaces presented to the breeze. None of the wheels which ran indifferently in either direction would really *run,* with its convex back presented to the wind. No. 4 was the only one that ran with any speed with either side exposed to the wind. This too was the only wheel with both sides plain and exactly alike.

The one particular in which wheels No. 5 and No. 6 appeared paradoxical in performance was in the fact that when running freely without any applied load, it was found that the wind pressure against their wings was more than three times as great as when they were clamped to their axles so as to remain stationary. Fig. 3 shows an apparatus designed to weigh the pressure of the wind in an axial direction by means of weights placed in the pan hung from the horizontal arm of the balanced T lever. The pressure against the wings increased with increase of speed of revolution until at the maximum the pressure was greater than that on a solid disk of the same diameter as the wheel.

In measuring the power of the windwheels with a dynamometer we have invariably found that speed of revolution was reduced with every increase of load applied with a brake, and that the torsional effort of the wheel as shown by the dynamometer was progressively reduced as the speed of revolution increased. This, too, accords well with common sense. Nevertheless, the facts are as stated in the preceding paragraph. Also wheels Nos. 1, 2 and 3 received nearly as great wind pressure at full speed as Nos. 5 and 6, and fully as great, or greater, than the pressure against a solid disk of the same diameter.

These experiments serve to throw some light on certain puzzling facts which force themselves on the attention of those who observe closely the flight of soaring birds as they rapidly float along on rigid wings without any apparent means of propulsion. Certain authorities have asserted that propulsion in soaring flight must be due to a negative inclination of the wings sustained by rising currents of air. We believe that both of these professed observations are products of the imagination rather than of actual vision, though an equivalent must be substituted for the supposed rising currents.

If rising currents of air do really account for the possibility of soaring flight, it is not necessary to assume that the wings must have negative angles; since these experiments show that wings of windwheels (Nos. 1 and 2), without any weather angle are propelled by wind whose direction is at right angles to wing motion after sufficient headway has first been attained. In the same way birds must somehow get well started before they can soar. Mr. Chanute places the

minimum soaring flight of birds at about seventeen miles per hour.

Eiffel has shown that an airplane wing driven against the air, or exposed to wind impinging in a direction parallel with the chord of a wing having its concave surface underneath (that is, without weather angle), experiences a very decided upward thrust and that a negative angle of three degrees does not entirely neutralize the lift. Our experiments show that a windwheel whose wings have a weather angle of three degrees will run backwards after being sufficiently started in the reverse direction. From this it follows that a bird's wings receive upward thrust in the same way by reason of their forward motion. We also know that vibrations in the air, or air waves, which crowd against the wing incessantly from every direction, all act more strongly against the under concave surface than against the upper surface which is convex.

The difference of thrust due to air vibrations against the two surfaces of opposite curvature is not very great unless the wing is traveling at considerable speed. The rapid motion multiplies the differences of opposite thrusts and produces an aggregate upward thrust sufficient to sustain the bird without supposing the necessity of rising currents of air. Prof. Langley has partially explained the effect of air waves on the wings of soaring birds in his treatise dealing with The Internal Work of the Wind, though he accounts for the action of horizontal impulses only, and it is not necessary to suppose that the bird instinctively adjusts its wings fore and aft, in the light of Eiffel's experiments. It is clear that horizontal impulses give a resultant lift whhether impinging from the front or from the rear against horizontal crescent shaped wings.

Rising air currents more generally prevail over heated land surfaces. But what goes up must come down, and the cold southern seas must experience an excess of descending air currents. Yet there is the home of the most noted of soaring birds, the Albatross, a bird that habitually soars, and evidently does not have to hunt out exceptional streaks of rising currents or follow devious courses for the sake of their assistance.

How Insects Steer Themselves While Flying*

"Weight Steering" and "Pressure Steering"

By Dr. F. Stellwaag, Privat Dozent at the University of Erlangen

THE positions of a hovering body in space is dependent upon the situation of the center of gravity on the one hand and upon its surface on the other. When any flying animal, therefore, wishes to alter its direction while flying it must alter either the location of the center of gravity or else the surface of its body. It both cases we are concerned with steering arrangements, but the manner of functioning is different in the main. "Weight steering," if I may so express myself, operates by means of a change of equilibrium due to a shift of the center of gravity. Thus it is to be supposed that the body of an insect is more heavily loaded on one side or the other when the abdomen is curved towards the right or towards the left. Consequently the body must swerve in a direction which corresponds to the resultant between the direction of the force of gravity and the original forward moving direction of the wings. This sort of steering is in use in many airships by means of a sliding weight. In such cases it is, of course, the weight alone which plays a decisive part.

Just as it is possible to think of the weight of a body as being united at one definite point, *i. e.* the center of gravity, in the same way in the case of a body which is moving forward and which is therefore subject to the resistance of the air, we can think of a single point, *i. e.* the center of pressure, as representing the force of the air pressure against the surfaces involved. The position of the center of pressure changes as soon as the surfaces of attack of the body of air in motion are altered. If this alteration is one-sided a change of direction will be produced. This "pressure steering" never operates through weight and may be even regarded theoretically as being without weight. The more rapid the motion of the moving body the greater the amount of work done by this pressure steering, since it operates by the capacity for work of the secondarily occasioned air pressure. The steering of water craft and air craft comes under this head of pressure steering almost without exception. It may be termed extra-directive steering in contrast to intro-directive or weight steering. It is precisely this difference which makes it possible to understand various phenomena concerned in the manner in which various animals move and to throw light upon various problems which are generally very obscurely treated in text books on biology.

We are chiefly indebted for such knowledge as we possess concerning the steering capacity or insects to Jousset de Bellesme.[1] His experiments with insects of all kinds led him to believe that the direction during flight is determined by the position of the head and thorax, *i. e.* of those parts of the body which penetrate the air; in his opinion it depends upon the center of gravity and upon the position of the axis of support, both of which are movable. In most cases it is the center of gravity alone which is responsible for an alteration of position. In only a few insects do the functions of motion and direction coincide, those which possess direct flying muscles and can therefore move the wings separately, like the *Aeschna.* However the long and movable abdomen plays a part in modifications of the movement, as can be plainly seen in the Agrionids. The same thing may be considered to be true of the butterflies whose wing movements resemble those of birds.

In the Hymenoptera the wings serve merely to produce forward motion, the abdomen is very movable and is thus capable of altering the center of gravity and therewith the direction of movement by taking different positions. If the insect is deprived of this freedom of motion in the abdomen, it appears to be still able to fly but no longer to steer itself. In the *Megachile, Polistes* and other Hymenoptera, the legs also take part in the shifting of the center of gravity. In the Orthoptera the abdomen is only slightly movable; the hind legs might here be concerned as an organ of direction were they not specialized for the function of jumping. They are poorly adapted for steering and as a matter of fact the Acridia and Locustidae are but ill able to guide themselves.

In the insects just mentioned both wings on each side are designed for the purpose of forward movement. In the insects now to be treated of, functional adaptation has created organs suited for definite purposes. One pair of wings is used

*Translated from the *Biologisches Centralblatt* (Leipzig), January 20, 1916.

[1]Bellesme, Jousset de. (a) Recherches Exper. sur la fonction d. balanciers chez les insectes dipt. (Exper. Nesearches Concerning the Function of Balancers in Dipterous Insects). Paris, 1878. (b) Sur une fonc. de direct. d. le vol des insectes. (Concerning a Function of Direction in the Flight of Insects). C.I. Ac. Fr., 1879 b. vol. lxxxix.

for forward movement and the other for the alteration of the direction. Since in the beetles the abdomen is closely united to the metathorax, it possesses but slight freedom of motion. However, there is no need for it to be movable since the wing covers or elytra have assumed the function of steering. During the active flight they are lifted above the thorax and are thus placed above the center of gravity in such a manner that even very slight variations of their position serve to influence the position of the latter. If the wing covers are removed the insect is no longer able to direct its flight. This shifting of the center of gravity has been demonstrated with precision by Plateau.[2] Only those insects belonging to a small group, the *Cetoniidae* fly with covered wings, an interesting circumstance since the wing cover in this case acts upon the axis of sustentation which forms a *transition* to the state of complete differentiation in the *Vittera.*

Among these the capacity for steering is best developed. Only one pair of wings is employed for forward motion. But slight mobility is possessed by the abdomen and thus the only organ for determining direction is the "balancer" on each side. When this organ is amputated the center of gravity is shifted too far forward and this so affects the power of flight that the insect falls to the ground. If now, however, a small weight is attached to the abdomen so as to shift the center of gravity the proper distance to the rear, the insect is capable of flying in any direction in spite of the loss of its balancer.

According to the view of Jousset de Bellesme (just quoted) insects direct their flight, therefore, entirely by weight steering. In this he agrees with Plateau, Bert,[3] and other authorities. This opinion is contradicted, however, by the information now available. I have myself proved by anatomical-physiological and experimental methods that the wing covers of beetles by no means exercise the rôle hitherto ascribed to them.[4] They operate by pressure steering, or still better as stabilizing planes. In the balancers of the Diptera, however, a complex nervous apparatus has been detected by means of which flies perceive variations of equilibrium. That in spite of this they might influence the direction of the insect's flight as a weight rudder, was held indeed twenty-five years ago by Weinland.[5] But this view finds but little support at present; it certainly seems doubtful at least that an organ so light in weight is capable of producing an alteration in the direction of flight. This would be possible only in case the elytra lay in the same direction as the obliquely situated line of gravity. Various measurements made by me, however, proved clearly that the center of gravity in the different kinds lies behind the roots of the elytra, and that, furthermore, it is shifted still further to the rear after the filling of the intestine or the increase in size of the gonads.

Amans[6] has recently expressed an opinion contrary to that of Bellesme. According ot him insects steer by means of pressure. He calls special attention to the wave like form of the part of the body which is presented to the current of air during the act of flight. As he points out the profile of this part of the body forms a "line of double curvature." It is most marked in form in the Ichneumonidae in which the abdomen is shaped like a sickle. Within certain limits this wave form is of great advantage to the insect during the act of flight from a dynamic point of view; by reason of the fact that its curvature can be varied by the motion of the abdomen it operates as a pressure rudder. The abnormal curvature in the Ichneumonidae would be a hindrance except that we are here concerned with insects which fly very rapidly. For this reason, however, the air pressure is very slight and this has the effect of causing the body to take a horizontal position during flight. In this case, therefore, the abdomen pays the same extra-directive rôle that is exerted by the outspread and downward pressed tail-fan of many birds. Thus Amans, though starting from the same premises as Bellesme, comes to directly contrary conclusions, which appear to me to possess a greater degree of probability. However, in my opinion the problem of the steering capacity of insects deserves renewed and thorough examination.

Serious difficulties attend such an experimental investigation. It is not always possible to remove parts of the body of an insect without injuring the organism. . . . Furthermore, a decrease in the capacity for movement seldom attains the desired object, since such a decrease . . . is apt to affect the steering. For this reason I have made use of entirely different methods.

Anyone who has watched insects closely during their flight knows that they display extraordinary skill in steering in every direction and often deviate instantly from the original path. In case the steering be accomplished by the legs and abdomen in a manner similar to that attained by manipulation of the bow or stern rudder in the case of air and water craft then presumably the greater the skill with which the insect changes its direction the more definite the required alteration in the steering organ. However, I was never able to perceive by direct observation any distinct alteration of the position of the legs and abdomen for the purpose of steering. At first I ascribed this to the inherent difficulty of following with the eye the swift movements of the creature at the decisive moment; however, I obtained a welcome subject of study in the *Libellae.* In cloudy weather or at sunrise and sunset the motions of these insects are feebler than usual and as a result the change of position in the legs and abdomen can be readily followed. The *Libella* (dragon fly) readily steers itself forward, backward, or sidewise without moving its long abdomen for an instant, although the latter is admirably adapted for a rudder. In a swift flight, particularly, for example, when the insect is rapidly descending, the abdomen alters its position. But even in this case it does not alter the direction of flight, but is passively curved, on the contrary, after the insect has taken its new direction.

These observations, I believe, to be entirely trustworthy in spite of the contrary views of many authorities; but they are not yet entirely conclusive since they are subjective in character and are confined to a few favorable examples. In order to attain objective certainty likewise, I made use of a simple arrangement. When parallel rays fall on a body in a vertical direction the body casts a sharply defined shadow of full size upon a surface which is likewise vertically placed. . . . By this method I obtained, of course, only silhouettes, but these presented images of a character which a camera cannot furnish since the latter gives a sharply defined image only at a certain definite distance and an image, moreover, which is usually reduced in size, and since, furthermore, the swiftness of the flight prevents a sufficient time of exposure.

After many failures and after overcoming very serious difficulties I have succeeded in obtaining during the last few years a series of views of different insects by means of light falling through a shuttered slit. In no case have I been able to observe a change of position in the abdomen during the alteration of the direction.

I obtained the same results experimentally. According to their histological structure the elytra are to be regarded as sensory organs of equilibrium. Each passive movement

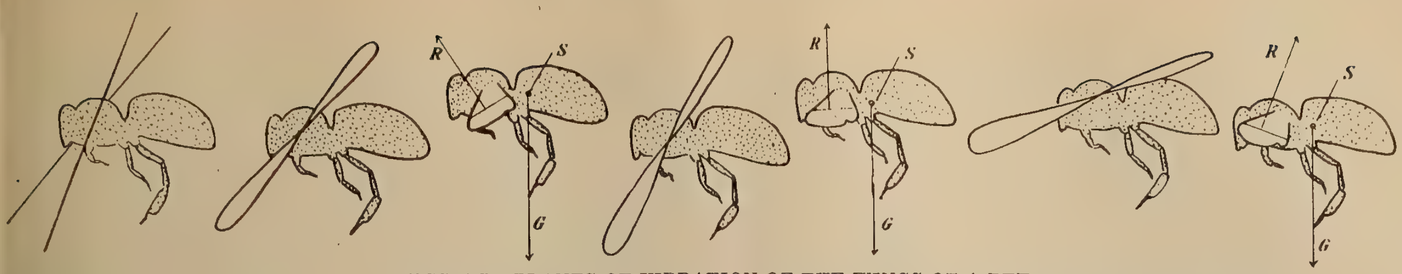
[2]Plateau, f. Recherches exper. sur la position du centre de gravité chez les insectes (Experimental Researches Concerning the Center of Gravity in Insects). Arch. d. sc. phys. et Nat. New Period, vol. xliii, 1872.

[3]Bert, Paul. Notes divers sur la locomotion chez plus. expec. anim. (Some Notes Upon Locomotion in Various Species of Animals.) Mem. of the Soc. of Phys. and Nat. Sc. of Bordeaux, Paris, 1866.

[4]Stellwaag, F. Der Flugapp. d. Lamellicorm (The Flying Apparatus of the Lamellcornia). Zts. f. wiss. Zoöl., vol. cxiii, 1914.

[5]Weinland, E. Ueber die Schwinger d. Dipteren (Concerning the Balancers of the Piptera) Zts. f. wiss. Zoöl., vol. li, 1890.

[6]Amans. (a) Géom. descript. et compar. des ailes rigides. (Descriptive and Comparative Geometry of Rigid Wings). Fr. Assoc. for the Advancement of the Sciences, Congress of Ajaccio, 1901. (b) Sur les lignes à double courb. dans locomo. animale: applications indus. (Concerning Lines of Double Curvature in Animal Locomotion: Indus. Applications.) Reports of the V. Internat. Zoölog. Congress. Nachtrag. (c) En planant (On Hovering); Causeries d' aviation (Talks on Aviation).



FIGS. 1-7. PLANES OF VIBRATION OF THE WINGS OF A BEE

Fig. 1. The different planes of vibration of the wings on each side of a bee when steering. The vibration of the wing is stronger on the right side of the animal than on the left and causes a swerving towards the right. Figs. 2-7 show that the planes of vibration of the wings (in the form of the figure 8) and their positions vary according as they have a forward motion (Figs. 2 and 3), a hovering flight (Figs. 4 and 5) or a backward flight (Figs. 6 and 7). G = direction of gravity; R = resultant of the forces acting upon the wing while beating; S = center of gravity.

of the balancer in a definite plane of space brings to the exterior the termination of a definite group of papillae at its base and orients the body not only with respect to direction but also with respect to the rapidity of flight. But since, as Baunack[7] points out, the function of all organs of equilibrium consists "in so influencing the locomoter organs that a definite position of the body results from their regulatory movements" the fly must react when altering its position with such parts of the body as play a decisive part in the alteration of direction. The more skilfully and the more frequently the insect repeats the steering operation in a free flight, the more clearly marked the reaction. I have already remarked that the wing coverings are not to be regarded as weight rudders. On the other hand, neither are they capable of functioning as a pressure rudder, since they are placed behind the axilla of the fore wings where the path of the beat of the wings is slightest and since they vibrate in the same direction and with the same rhythm as the fore wings. Furthermore, they are covered with the *Squamula thoracalis* as in the *Tabanidae*, *Syrphidae* and *Muscidae*. There are few parts of the body, in fact, which are so well shielded from air currents during the act of flight as the elytra. According to the prevailing view therefore, only the legs and abdomen can function as a rudder.

In my experiments I made use of specimens of the three above-mentioned families of Diptera which not only belong to the best flyers among the Diptera but even among those of flying animals of all sorts, steering themselves with surprising skill and certainty and likewise being extremely adept at sudden descents or what may be called pouncing flights. I grasped them by the thorax by means of a pair of nippers. As soon as the insect began to beat its wings I placed it in different positions so that it now lay on one side, now upon its back, or held a position at a varying angle wth respect to a horizontal line. The abdomen constantly remained motionless in the longitudinal axis of the insect. It was noticeable that the little creature constantly attempted to clasp the nippers. I prevented this by grasping the abdomen with the implement. This made it possible also to observe the positions of the legs. These were entirely voluntary and their alterations of positions could not be regarded as compensation movements with respect to the altered position of equilibrium. I also conducted similar tests concerning the position of the legs, with wasps, bees, bumble-bees, sphinx moths and the *Aeschna grandis* L., always with the same results.

All these observations justify us in concluding that the views of Belesme and Amans are incorrect. Insects employ neither the legs nor the abdomen as a rudder.

Before I began my experiments with the nippers I made a preliminary test (of imperfect character) by piercing the thorax of the insects examined with an extremely long fine needle. Thereupon it frequently happened, especially in the case of the Diptera, that the insect turned with increasing speed to the right or the left side, so that it soon began to revolve around the needle. These movements took place without altering the position of the extremities or of the abdomen and the thought was suggested that it is the wings which accomplish the steering action.

The manner in which the wings of insects move has been studied by Marey[8] by means of very clever experiments. He has thus discovered that the movements on each side of the body are always entirely synchronous. Thus, the number of beats of the right wing in a given time always agrees perfectly with that of the left wing. This can be very beautifully demonstrated; on pressing the back of the thorax of an insect that has just been killed, both wings at once rise simpultaneously. If one wing be moved without otherwise touching the tergum the wing on the other side makes identical or similar movements. . . . The fact of this synchronism induced Bellesme, as he expressly states, to seek for some steering device outside of the flying apparatus.

Since the experiments described above obliged me to believe that the insect steers by means of its wings, I continued my experiments along this line. I varied the position of the body during the movements of the wings, as in the previous case, and proved that the insect revolved now in the same direction as the hand of a watch and now in the reverse direction, according as I rotated the little creature about its longitudinal axis, which furnishes a proof to begin with that disturbances of the equilibrium of the body are compensated by means of wing movements. Rotations of the body took place, however, when the needle was held stationary in a vertical position. It was evident that the insects experimented upon endeavored in this manner to escape from their uncomfortable position, *i. e.* they tried to steer themselves.

I was able to determine the manner in which insects rotate about the needle by grasping them with the nippers and gently inclining them in different directions with regards to space. Thus the plane in which each wing vibrates was altered. The variatons from each other of the planes of vibration can be best observed from the side, as shown in Fig. 1. In order to make these variations perceptible in a front view, it is only necessary to gild the wings as Marey suggests and allow a beam of light to fall upon them in a definite direction. In this case it often happens that one wing appears dark while the other reflects the light to the eye of the observer.

In many cases the insect not only alters the plane of vibration but also the amplitude of vibration of one wing so that the wing-beats on the two sides of the body differ in extent. These phenomena, however, do not contradict the fact described above of the perfect synchronism of the wings. A person seated in a row boat is readily able to vary the manner of the oar beats on the two sides independently provided only the rudder is moved at the same time. The experiments with *Diptera* and with the *Sphinx pinastri L.* proved that it is possible for the amplitude of vibration of one wing to be

[7]Baunacke. Zur Frage der Statocystenfunktion. (Concerning the Problem of the Function of the Statocyst). Biolog. Centralbl., vol. xxxii, 1913.

[8]Marey. Mém. sur le vol des insectes et des oiseaux (Memoir Concerning the Flight of Insects and Birds). Ann. des Sciences nat. Sér. 5, Zoöl., vol. xii, 1869.

constantly decreased until the wing is entirely at rest while the other wing continues to vibrate. Such alterations in the amplitude of vibrations have also been observed by Boss[9] as shown in his moving pictures of flying insects. He has expressed the view that they are of importance with respect to the steering, the stabilization, and the rapidity of forward movement of the animal. But they not only play a definite rôle but likewise make possible the alteration of the direction of the wing-beat, and also facilitate steering, since the flying apparatus of insects is likewise their steering apparatus, as I believe I have sufficiently proved.

However, it is necessary to go somewhat further to explain theoretically the phenomena of steering.

During rest the wing of an insect usually presents a flat surface. So long however as a surface is uniformly even it is unable to function as a flying surface; for when it beats downward the particles of air are compressed and at once exert, since they immediately seek to return to their original position, an opposite pressure upon the under side which may be designated as anti-parallel to the original direction of pressure, and this would only be increased by the increased expenditure of energy on the part of the insect. However, an insect's wing not only exerts a lifting power but also at the same time a forward impulse, and this occurs, to begin with, by means of the varying elasticity of the wing surface. The *costa*, *subcosta* and *radius*, in the different varieties, stiffen the forward edge, either separately or unitedly, so that this edge is able to split the air like the blade of a knife. But the surface lying behind it increasingly yields the farther it lies from the aforesaid front edge, as can be plainly observed in the wing of a beetle, in which the strength of the veins which support the membrane plainly decreases. The case is analogous in insects in which the hind wings are reduced in size and therefore less powerful than the fore wings, as, for example, in the Hymenoptera and in many Lepidoptera. In order to make a physiologically uniform and effective wing surface the hind wing must be united to the forward wing. This is accomplished in Hymenoptera by means of a little hook and in the Lepidoptera by the clinging brush at the axilla of the wing. The chief value of this arrangement does not consist, therefore, in uniting the rear wing to the forward wing so that it can share the wing movement nor in increasing the beating surface of the wing, but rather in providing the fore wing with a soft or flexible rear edge. During the act of flight consequently the wing constantly attains a weak-formed diagonal. The particles of air struck and compressed by it at once seek to return to their original position and are forced to flow off to the rear beneath the soft rear edge of the wing. In doing this they exert a forward pressure upon the wing by means of which the entire body receives a more or less powerful forward impulse. The form of the wing surface and its physical structure, in connection with the rotation, is therefore an indispensable prerequisite condition for flight. The dammed up air formed beneath the downward beating wing creates on the underside of the wing a pressure which constantly acts in a perpendicular direction to the various portions of the surface. Since the whole surface is curved through the lifting of the rear edge, the chief resultant of the different parallelograms of force does not lie in a perpendicular direction to it, but is somewhat inclined towards the forward edge (Figs. 3, 5, 7, *R*). The force of gravity drawing the body downwards works against the upward impulse.

So long as the wing of the insect is large enough to bear the weight of the body and move forward as in the case of the Libellae it is not forced while beating its wings to make a special alteration of position. If, however the wing is too small in proportion to the body it is obliged to execute rapid and complicated rotary movements (cf. Stellwaag[10]) in order that the rigid forward edge may first penetrate the air and occasion a vigorous downward flow of the particles of air beneath the rear edge. What an amazing amount of energy is expended by the wings when they maintain the elasticity of their rear edges by sharp rotation, is shown in extreme form by the Diptera.

If the insect is merely seeking to go forward it must create for itself a strong impetus. It then so places its wings (as shown in Figs. 2 and 3), that the resultant of the forces is strongly inclined towards the direction of gravity (in Figs. 2 to 7 the direction of the resultant represents an average value, for the wing rotates a little bit as mentioned above when it beats downward). In the hovering flight which is especially preferred by the Syrphidae, the vibration plane of the wing is so inclined towards the horizontal (Figs. 4 and 5) that the resultant coincides with the perpendicular direction. Hence the forward impetus is lacking while the upward force and the force of gravity are in equilibrium. In this position a vertical flight upward is possible when the upward impetus is augmented by rapid wing beats. If the resultant tends towards the perpendicular a movement of the body backwards ensues (Figs. 6 and 7).

In all these cases the wings on both sides beat synchronously—with the same amplitude and in the same plane of vibration—and the body retains the original direction. But if one wing is rotated upward in such a manner that it employs more of the upward impulse than of the forward impulse, there takes place a wavering or rotation about that side of the body which generates the lesser amount of forward impulse (in Fig. 1 this is the right side of the insect). However it is also possible for the amplitude of the wing beat on one side of the body to decrease even to the point of entirely ceasing. The consequence of this is that the body inclines towards this side; it will not fall to the ground since the wings of the other side still carry it forward but it will instantly deviate from the former direction. Through the fact that insects can thus make other movements upon each side, they are able to attain a quite surprising degree of facility in the alteration of direction by a skilful combination of the various wing beats. In Figs. 8 and 9, I have represented the paths of flight pursued by a honey bee and a fly (*Eristalis tenax*) . . . the path is composed of various kinds of movements, now a section of a circle is described in which the head goes first in the direction of the movement and now the insect rapidly turns aside from the original direction without altering the position of the body with respect to space. It is

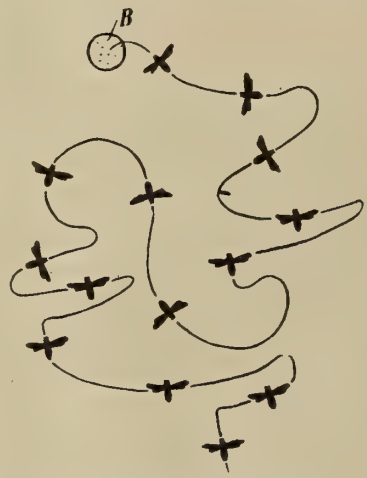


FIG. 8. PATH OF FLIGHT OF A HONEY BEE SHOWN IN THE ACT OF LIGHTING UPON A FLOWER BLOSSOM (B)

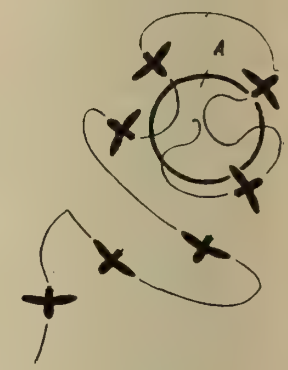


FIG. 9. PATH OF FLIGHT OF AN *ERISTALIS TENAX* WHICH IS FLYING TOWARDS AN ASTER BLOSSOM (A)

[9] Boss, Vergl. Untersuch, ueber die Flugwerkz. d. Insekt. (Comparative Studies of the Flying Apparatus of Insects.) Section 2, Verh. d. deutsch. Zoöl. Gesellsch. Collection 24, 1914.

[10] Stellwaag, F. (a) Bau u. Mech. d. Flugapp. d. Biene. (Structure and Mechanism of the Flying Apparatus of Bees.) Zts. f. wiss. Zoöl., vol. xcv, 1910.

also possible for rotary movements around the point of the abdomen or around the head end of the body to take place. I have observed similar steering movements in numerous other Diptera, in Hymenoptera and also in night moths. The butterflies that fly by day are less skillful. On the other hand their so-called "creased" path of flight can undoubtedly be traced to the imperfect synchronism of the two wings. Especial conditions mark the flight of beetles. Forward movement in a straight line appears to give them but little difficulty. On the other hand they find steering to one side made difficult by the fact that the wing covers obstruct the current of air. For this reason beetles tumble towards the left and right as can be readily observed.

When we compare various insects with respect to their steering capacity we are led to conclude that skill in flying and skill in steering are closely connected, whereas skill in flying and the form of the body do not exhibit such a close connection. The greater the capacity for flight the better able the insect is to steer. Since however capacity for flight depends upon the specialization of the motor apparatus and especially of the axilla of the wings, it is possible to divine the degree of capacity for steering from the morphological nature of the thorax and especially of the axilla of the wings. This fact is of great importance with respect to the anatomical-physiological analysis of the flying apparatus of insects. Many elements of the axilla probably play a part in active steering, and one or another muscle may be brought into service so that its function may be judged from this standpoint.

The problem of steering in insects is closely connected with the question as to how equilibrium is maintained during flight. Among the great number of flying insects only a disappearing few possess static organs. Thus far they have been found only among the Diptera in the *Chermes* and *Phylloxera*. This is the more remarkable since it is just in such excellent flyers that the maintenance of equilibrium must be of the greatest importance. Bethe[11] was of opinion, therefore, that in all insects which possess no static sensory organs the position of equilibrium is maintained mechanically. His experiments are of interest here only in so far as they concern flying animals.

Bethe's methods consisted in first stupefying or killing the animal with chloroform and then allowing it to fall, with the wings arranged in characteristic positions, either freely through a space or else within large wide cylinders. No matter what position the animal was in at the beginning of the experiment it always assumed the abdominal position during the fall and retained it till it reached the ground. "That the form of the animal exerts great influence in this respect is shown by a glance at the relation between the wings and the body. But that in the case of most of the animals examined the relation between the air and the substance of the body exerts an influence upon the maintenance of the abdominal position is shown by the circumstances that with the exception of a few they were forced upward in water (specifically heavy) in the same position in which they fell to the ground when in the air."

Amans expresses a similar opinion. "We are obliged to regard the manner in which the body of wasps is held as a means for accomplishing longitudinal stabilization. The lower surface of the body is strongly convex and we know that with such a curvature stabilization is automatic. This can be demonstrated experimentally by allowing a sheet of paper bent into a concave convex form to fall to the ground—it will always fall upon the convex side."

Bethe's subjects of experiment and Aman's convex sheet of paper coincide with respect to the fact that they have no individual mobility. They resemble perfectly the passive hovering or floating organisms which assume a definite position with regard to space within the medium which surrounds them, and which automatically revert to that position when their equilibrium is disturbed.

[11]Bethe. Weber die Erhaltung des Gleichgewichtes. Biolog. Centralbl., vol. xiv, 1894.

But the views of Bethe and Amans fail to correspond with the actual facts. My experiments with insects which lack static sensory organs (wasp, sphinx, etc.), have proved that such insects as well as the Diptera promptly react to every disturbance of the position of equilibrium by means of compensatory alterations of the plane of vibration or of the amplitude of the wing-beat, *i. e.* that they perceive disturbances of equilibrium and actively return to the position of equilibrium by means of pressure steering. This is by no means singular since the orientation of animals in space is not invariably accomplished through static sensory organs, but is also assisted by the sense of light. Bethe omitted to take into consideration in his experiments that there are very few insects which are capable of hovering. The overwhelming majority are obliged to make sudden and sometimes rapid wing-beats in order to generate an effective forward impulse and upward impulse.

DISINFECTION BY HOT AIR.

When hot air is used for disinfecting purposes the result is due to two factors. Certain sensitive micro-organisms are killed by desiccation, especially the plant forms which contain about 80 per cent of water. The spores are generally very resistant since their cellular body consists of a highly concentrated albuminoid substance which contains very little water and since they are also protected by membranes of cellulosic character. Hot air also kills by the coagulation of living protoplasm and this effect is produced more rapidly by moist heat (steam) than by dry hot air. Steam also has the advantage of penetrating the articles to be disinfected more rapidly than does dry air; the latter penetrates articles of large size very slowly because the air which they contain forms an obstacle.

Unfortunately, however, steam is very apt to affect clothing and other articles injuriously; it causes the fading or running of colors, alters the surface of leather, causes spots of rust on metal, makes glued articles come to pieces and affects the shape of certain articles of clothing; moreover, it is more costly to use than dry hot air. These various considerations have induced Mr. H. Rautmann to attempt to improve the dry air method by raising the air to a bactericidal temperature and by forcing it to penetrate the objects to be disinfected by means of violent agitation. The apparatus employed is described in *L'Igiene Moderna*. It consists of a closed chamber in which hot air is made to circulate with great rapidity by means of an electric motor. Since the air which circulates is unchanged the quantity of heat required is very small and the expense is correspondingly low. A metal thermometer is attached to an electric contact apparatus in such a manner that when the temperature has reached a certain degree the fuel combustion diminishes automatically, while it is increased, on the other hand, whenever the temperature falls below a certain limit. In this way great uniformity of temperature is obtained in the interior of the disinfecting chamber. Actual tests in different parts of this chamber at the end of half an hour, showed only three degrees of difference (155° C. and 158° C.). The author experimented with the lice found on swine; these were enclosed in woolen bags and placed in the apparatus. They were found to be dead in from fifteen to sixty seconds—in the same way the spores of anthrax and the typhoid bacillus were completely destroyed.

Animal parasites of various kinds are readily destroyed by a few minutes' exposure. Among the bacteria the plant forms were quickly killed as soon as the temperature reached 100° C. (212° F.) and since most pathogenic germs have no spores this temperature (that of boiling water) is sufficient to disinfect articles contaminated with the germs of typhoid fever, cholera, small pox, influenza, dyphtheria, tuberculosis, glanders, chicken cholera, etc. The apparatus can also be employed for destroying spores by raising the temperature of the air to the required degree.

Do Animals Ever Use Artificially Improved Tools?

Some Examples of Resourcefulness and Ingenuity

A WELL-KNOWN German writer on natural history, Wihelm Boelsche, recently propounded to the readers of *Kosmos* the interesting query as to whether there exist authentic cases of the use of artificial tools, *i. e.* of special implements to serve special ends, on the part of the lower animals. Mr. Boelsche inclines to the belief that instances of such nature do occur, but considers the question still an open one and invites his readers to express their views upon the matter either in the negative or the affirmative, as the case may be. Meanwhile he cites certain instances which may be considered as bearing on the question, quoting freely from such established authorities as Doflein and Bugnion. He calls attention to the fact also that some scientific men hold that the eoliths, or shaped stones of the Tertiary Age, which are generally believed to be the first tools devised by the dawning intelligence of man, may really have been made by some superior member of the Primate Family. In either case the question is fundamental both with respect to natural history and to the first glimmerings of that evolution of the powers of the human brain to which we give the name of "culture."

One of the first examples given by the author is quoted from Prof. Franz Doflein of the University of Breslau and concerns the ant known as the *Oecophylla smaragdina*, of which this authority has made a close study. These insects do not build their nests in the ground, but high in the open air,

FIG. 1. PRIMITIVE TOOLS OF MAN
1 and 2 show simplest shaped implements made by Tasmanians; 3 and 4 so-called eoliths of the Middle Tertiary Epoch supposedly the first artificially-improved tools made by man (taken from Klaatsch and Verworn).

FIG. 2. LEAF NEST MADE BY OECOPHYLLA SMARAGDINA AFTER DOFLEIN
Reproduced from Sajo, *Ameisenstaat.*

forming them by spinning together the living leaves of bushes and trees (Fig. 2). When Doflein tore apart two of the leaves forming such a nest he observed that a line of ants ranged themselves along the edge of one leaf, holding fast to it with all six feet and stretching out their heads until their mandibles were able to lay hold of the edge of the opposite leaf. "Then," says Doflein, "they slowly and cautiously drew backward, walking carefully backward, one foot behind the other, so that the two leaf-edges which had been split apart gradually approached each other" (Fig. 3). Other observers, remarks Boelsche, not only confirm this, but have even seen ants form a chain quite like a line of gallant firemen, until the foremost was able to seize the edge of the further leaf, in cases where the split was unduly wide. But when the two leaves have been drawn together the domicile is still imperfect. The edges must be attached to each other, and the workers are unable to accomplish this, since they themselves possess no spinning glands. But what does it matter? These barren but resourceful females run to the nursery, tenderly pick up their better equipped infant charges, and rush again to the breach in the walls, and let the babies bind it together once more with the tiny but tenacious threads they spin (Fig. 5). Doflein thus describes this curious operation: "They were by no means merely seizing the larvae in order to carry them to a place of safety, but came straight to the very point of danger, namely the breach in the walls of the nest. Arrived here they clambered about behind the row of ants which held the edges of the leaves together and moved their heads in a curious manner. They held the larvae firmly between their mandibles, seeming to exert a considerable pressure upon the middle of the body. This pressure may be of considerable significance, since possibly it exerts a stimulus upon the spinning glands. The scene presented a remarkable aspect as the workers clambered with their burdens along the line of those who were holding the fort, so to speak. While the latter took their position upon the outside of the nest the former carried on their labors upon the inside and were therefore more difficult to observe. However, after a little while I was able to see quite clearly that the workers held the larvae with the pointed head end of the latter directed upward and to the front and moved them continuously backward and forward from one side of the rent in the nest to the other. While doing this they first paused for a little while on the near side of the breach, as if attaching the thread spun by the larva to the edge of the leaf by pressing the larva's head against the leaf-edge; they then thrust the head across the split to the edge of the opposite leaf and repeated the same process there. As this continued one could see the cleft gradually filled in by a fine silky web spun by the larvae. The fact could not be doubted that the ants were using their young at once as spindles and as weaver's shuttles. Boelsch quotes Karl Escherich, the author of *Die Ameise* (Ants), to the effect that the feat described above is "probably the only case in the animal kingdom in which an animal makes use of a tool." The former writer, however, thinks this example, interesting as it is, does not answer his actual question, which concerns the use of *improved* tools, *i. e.* an implement in some sort modified by the user to serve his purposes, and thus differing, as does the eolith, from some natural object, such as a stick or stone, which men doubtless employed for one purpose or another, such as the beating of skins or the crushing of grain, before they conceived the idea of shaping one stone by means of striking or grinding it with another. The same objection holds good to various other acts of animals which might be cited in this connection, such as the ejection from his funnel-shaped burrow by the ant-lion of grains of sand which may strike some unhappy insect victim and thus facilitate his descent into the Avernus of the trap laid for him. Somewhat similar to this instance is that of the drops of water which are squirted by a certain Siamese fish at insects upon the bank of the stream. Again, apes can often be seen in the zoo cracking nuts with a stone as our earliest forefathers doubtless did, and as small boys do today. It has even been noted that the same monkey, or even a whole tribe, will employ the same stone—of a specially fit kind—time after time, until the stone is worn smooth from use, but of course this cannot be considered the conscious bettering of a useful implement, and never has a monkey been seen, according to Boelsch, to make use of a second stone to improve the shape of the first. However, he mentions in this connection a story told by Heck of a captive chimpanzee in Teneriffe who was accustomed to knock bananas off the bunch with a stick, and which, upon one occasion, when he had been offered a hollow

cane for this purpose, which proved to be too short, stuck a smaller cane inside and thus achieved his object. This certainly looks like a purposeful improvement of a tool.

Finally, Mr Boelsch refers to the acts of certain birds which have some bearing upon this question. Thus the great black Arara cockatoo of New Guinea, cracks certain extremely hard nuts in a very intelligent manner, first weakening the shell by sawing it with his hard beak and then breaking it. Furthermore, to keep his bill from sliding off the smoooth and slippery surface of the nut the bird wraps a bit of leaf about

FIG. 3. ANTS (*OECOPHYLLA SMARAGDINA*) MENDING A RENT IN THEIR NEST
After Doflein. From Sajo, *Ameisenstaat.*

to hold it steady while he operates on it. But of course in this case since the beak is one of the animal's own organs it can hardly be called a tool.

Still more remarkable, perhaps, is the practice of the large mottled wood-pecker called "the blacksmith wood-pecker." This bird is accustomed to thrust hard pine nuts into holes or crevices in the trunks or branches of trees, setting them upright so that they are held as by a clamp, thus enabling the bird to extract the seeds with greater ease. As Boelsche observes, this is quite workman-like in principle. But the wood-pecker often improves such a natural "vise" (which he makes use of repeatedly, as of a tool ready to hand) by hacking it with his beak, or he may even hammer out a hole to begin with if a natural one is lacking.

In conclusion the author asks his readers, as we have said, to furnish him with similar instances bearing on the direct intelligence of animals in making use of tools or in bettering

FIG. 4. ANTS (*OECOPHYLLA SMARAGDINA*) FORMING A CHAIN IN ORDER TO MEND THEIR NEST
After Bugnion, from Escherich, *die Ameise* (Ants).

the latter for the attaining of a given end, and the editors of *Kosmos* add a final note expressing the hope that the request will bring forth an instructive discussion of the matter, promising to forward communications to Mr. Boelsche.

THE OIL IN PEANUTS.

During the last few years in which there has been an urgent need of fats to be used for food and glycerin for explosives ,the subject of vegetable oils has received more than ordinary attention. Corn, oats, wheat, peach seeds, cherry seeds, prunes, olives, and the various nut kernels have each been carefully investigated as to their oil content, and the character and chemical properties of each oil accurately determined. It is thought that to repeat a similar study with the oil peanuts might not be without interest.

We procured a quantity of the fresh unroasted peanuts and removed the shell and adhering husk. The bare kernels were cut on a watch-glass with the aid of a knife. Twenty grms. of the chopped kernels were transferred in a "fat-free" sack to a Soxhlet apparatus, and extracted, with boiling ether for twenty-five and a-half hours, when it was found that all the oil had been extracted. The ether-oil mixture was transferred to a distillation flask, where the constituents were separated by fractional distillation. The oil as obtained was clear and slightly yellow in color, and made up more than 50 per cent of the weight of the original kernels.

The first experimental work on the peanut oil was to determine the iodine number. This we did by the Hanus method, and found the iodine number to be 94.5 and 95 respectively in two samples.

Another necessary procedure in the analysis of a specimen of oil is to determine its saponification equivalent. By the saponification equivalent we mean the relative amount of saponifiable oils in a given fat, expressed in terms of mgrms. of potassium hydroxide, that were used to saponify the oil.

FIG. 5. (*OECOPHYLLA*) WORKER MAKING USE OF A LARVA TO SPIN WITH
After Doflein. From Sajo, *Ameisenstaat.*

We proceeded with the saponification of the peanut oil, using the Koettstorfer method. The results obtained were 197, 200, and 202 respectively. This value is about 2 per cent. higher than the equivalent found by former workers.

The chemical composition and conduct of peanut oil (more often called arachis oil) is very similar to olive oil, and this fact has led a few dealers to adulterate the pure olive oil with this cheaper oil. The similarity of these two oils makes it difficult to determine accurately the percentage of each in a mixture. In a book, "Edible Oils and Fats," C. Ainsworth Mitchell makes a comparison of the typical values of the arachis and the olive oils as follows:

	Sp. gr.	Saponification No.	Reichert-Meissl.	Hehner value.	Iodine value.
Arachis	0.917	185.5	0.48	95.5	92
	0.9256	196	—	—	100.8
Olive	0.916	185	—	94.0	79.0
	0.919	196	—	96.0	93.0

The most reliable method of differentiating between the pure oils and a mixture of the two is to make a quantitative determination of the mixed arachidic and lignoceric acids. The method to be used involves the separation of the two lead salts by means of ether. These acids are recovered by crystallization from hot alcohol.

The well-known fact that glycerides of the oleic acid series may be converted into isomeric compounds by nitrous acid gives us the basis for the elaidin test, which we use in further investigation of the oil sample. Two cm. of the oil were mixed with an equal volume of concentrated nitric acid and a pale rose color was noticed after one minute. When heated on the water-bath for five minutes the mixture became yellowish brown. After cooling and standing at room temperature for twenty-four hours the mixture was solid.—*Nelda Schule* and *Harold L. Maxwell* in *Chemical News* (London).

A Theory of Metallic Arc Welding*

Metal Said to Be Projected from Electrode by Suddenly Formed Vapors

By Ralph G. Hudson

IN THE summer of 1918 the welding committee of the Emergency Fleet Corporation initiated an investigation of metallic arc welding in which special attention was to be given to the determination of the cause and nature of the transmission metal from an electrode to a plate. Although metallic arc welding had been employed successfully for a considerable period, it was appreciated that its application was based upon empirical methods, and to make greater use of such welding in shipbuilding it was evident that its basic principle should be investigated as thoroughly as possible so that inferior methods of metallic arc welding might be eliminated. The object of this paper is to present the results of an investigation of this character conducted in the laboratories of the Massachusetts Institute of Technology.

It should be noted that at the beginning of this investigation no satisfactory explanation had been given for the transmission of metal from electrode to plate. In downward welding the deposition of metal might be attributed to gravitational force, but in upward welding no such explanation could be offered. The fact that an electric current is employed in the process suggested the possible existence of forces of electrical origin which might pull metal from the electrode to the plate. Calculations of the magnitude of the electrical forces that may exist during metallic arc welding indicate that they are negligible and may therefore be eliminated as possible causes of the action. This view is further substantiated by the fact that satisfactory welding may be performed with current flowing in either direction or with alternating current, and that such differences as may exist with different directions of the current may be explained by consideration of the relative heating properties of such currents at the terminals of an electric arc.

Courtesy of the Electrical World and the American Welding Society

FIG. 1. EFFECT OF ARC LENGTH UPON SIZE OF ELECTRODE GLOBULE

At the right, a globule developed with a very short arc; in the middle, with a moderate length of arc; at the left with a very long arc. These are 3/16 in. electrodes magnified 6.8 diameters. The current strength in each case was 100 amp. Each globule contains a cavity; in the smaller globules, the cavities are usually open and resemble small drill holes, while in the larger ones they are usually closed and are surrounded by a thin skin of metal.

In conducting this investigation the writer, following the suggestion of the committee, first attempted to obtain a photograhpic record of successive phases of the welding arc by means of a high-speed motion picture camera. Owing to the intense luminosity of the arc itself, however, the films thus exposed show only various shapes of the arc itself and an occasional view in silhouette of the electrode, molten drops and plate. The principal use made of these films was to examine them one by one with a low-power microscope with transmitted light, the observations being noted later.

Instantaneous photographs of the welding arc obtained with a short-exposure focal-plane shutter suffered from the same domination of the plate by the arc to the exclusion of all other phenomena. While focusing the camera, however, it was realized that more could be seen with the eye on the ground glass than could be obtained photographically or by direct observation through dense glasses, so the writer began an extended study of metallic arc phenomena as seen in magnified form on the ground glass. In this manner the action of the arc could be examined without screening the eyes and with the further advantages offered by magnification and observation of the action in its true color.

When an arc is struck between a steel electrode and a steel plate the end of the electrode and a spot on the plate are heated to a high temperature and metal is transferred from the electrode to the plate. The electrode is heated to a higher temperature than the plate because the heating action of the arc is more concentrated in the case of the electrode and because the heat conduction away from the hot spot is greater in the case of the plate.

Since the melting points and other thermal constants of the elements[1] and their compounds in steel electrodes vary widely and their chemical affinities are quite different, it is to be expected that the constituents of an electrode subjected to a high temperature will change from solid to liquid or gaseous form successively and not at the same instant. Since the melting point of iron is higher than that of any other constituent of an electrode with the exception of carbon, which combines rapidly with oxygen at welding temperatures to form carbon monoxide, it is furthermore to be expected that in the welding process the iron constituent of the electrode will melt last.

The thermal changes just described are known to take place during the application of heat to any complex substance. In metallic arc welding the temperature changes which take place differ to a marked degree from the changes incident to the usual methods of heating metals in that a small mass of the electrode in welding is subjected to a high temperature for a very short interval of time. The distinctive thermal feature of metallic arc welding is then the sudden rise and fall of temperature in the metal transmitted to the plate. Under the circumstances it may be seen that the melting of the iron is delayed by the heat absorbed by the other constituents of the electrode and that this fact, together with the limited time of application of high temperature, disproves the possibility that the iron is completely vaporized in the welding process. For example, when a projectile is fired from a large gun, the initial temperature of the gas behind the projectile is believed to range between 3000 deg. and 4000 deg. C. Although this temperature greatly exceeds the melting point of the material of the projectile, there is little evidence of melting on the surface of the projectile because the projectile is not heated by the adjacent gas for a period long enough to melt its surface.

An increase of temperature in most materials is usually accompanied by an immense change in volume. While various changes in volume may take place among the constituents of

*Abstracted by the *Electrical World* from paper presented before American Welding Society.

[1]An analysis of steel electrodes usually reveals the presence of at least ten elements: iron, carbon, manganese, copper, sulphur, phosphorus, silicon, oxygen, nitrogen and hydrogen.

the electrode during metallic arc welding, the greatest possibility for such expansion may be found in the formation of carbon monoxide. It is therefore to be expected that a globule will be formed by such expansion on the end of the electrode during welding. Typical electrode globules developed in this manner by various lengths of arc during the welding process are shown in Fig. 1. Each globule contains a cavity which may be seen clearly during welding on the ground glass of the camera described above and is also present in the cold con-

Courtesy of the Electrical World and the American Welding Society

FIG. 2. SURFACE OF AN ELECTRODE ON THE ELECTRODE SIDE OF A LARGE GLOBULE

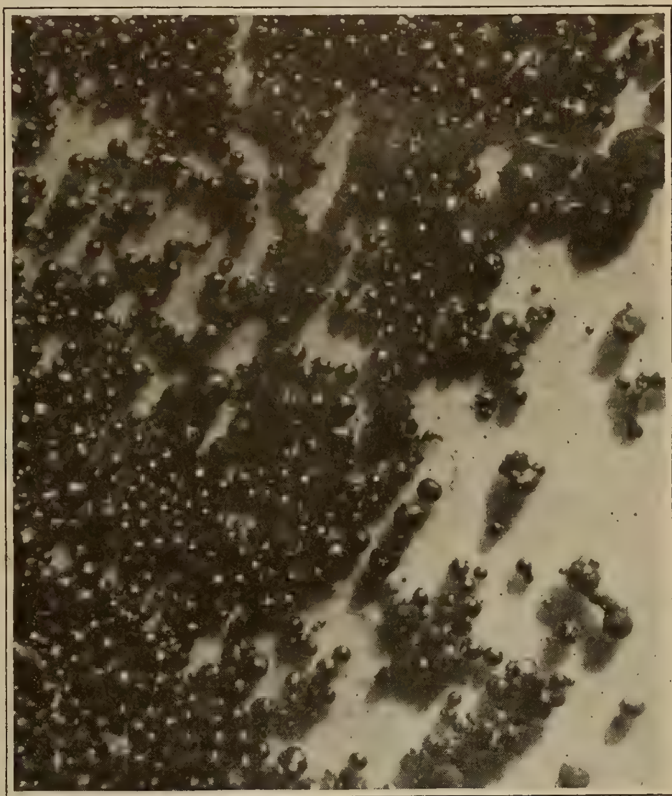
tracted globules shown in the figure. In the smaller globules the cavities are usually open and resemble small drill holes, while in the larger globules the cavities are usually closed and are surrounded by a thin skin of metal.

An electrode globule maintained in continuous contact with the plate to prevent the formation of the glaring arc and heated by a heavy current may be seen under magnification on the ground glass to expand and blow out minute particles at high velocity from the thinnest side walls, a contraction of the globule occurring after each expulsion of particles. The particles appear to originate in the inner electrode surface of the globule. If the globule is suddenly detached and the arc interrupted at the same instant in ordinary long-arc welding, the inner electrode surface of the globule presents the appearance shown in Fig. 2. The pitted electrode surface suggests irregular fusion due to different temperatures of fusion, vaporization and chemical combination of the ingredients under the influence of rapid changes in temperature.

Owing to the complex structure of the electrode, it is not easy to determine the exact nature of the vapor content of the globule. That the vapor consists partly at least of carbon monoxide gas is suggested by the fact that such globules do not form in general when the end of the electrode is heated in a reducing (deoxidizing) atmosphere. It is found impossible to weld with an electrode containing practically no carbon in a reducing atmosphere. In welding under water it was observed that bubbles of gas rise continually to the surface of the water and burn, indicating the possible dissociation of the water with the absorption of oxygen by the electrode and the rejection of hydrogen to the surface of the water. After a globule had been maintained for several minutes at high temperature in contact with a plate in air, it was observed that all expulsion of particles ceased. It may be inferred from this that all of the vapor-forming constituents of the globule had been burnt out.

If the electrode while welding is suddenly swept across an adjacent insulated flat surface, small spots of metal are found on the surface at regular intervals over the surface traversed by the hot electrode. (A magnified view of one of the spots is shown in Fig. 4) The same effect was observed by holding an incandescent electrode—just removed from ordinary welding—over the rim of a revolving wheel. It was determined in this way that the average frequency of projection was approximately one-fifth of a second, the projection terminating with the cooling of the electrode.

It would appear from the observed facts that the metal deposited during metallic arc welding is transmitted, in part at least, in the form of minute particles which are projected from the electrode globule by the internal expansion of some vapor, possibly carbon monoxide. The expelled particles pass through the arc too rapidly to become vaporized and reach the plate in a fluid state. If the expelled particles strike solid metal, they either ricochet along the surface—which ex-



Courtesy of the Electrical World and the American Welding Society

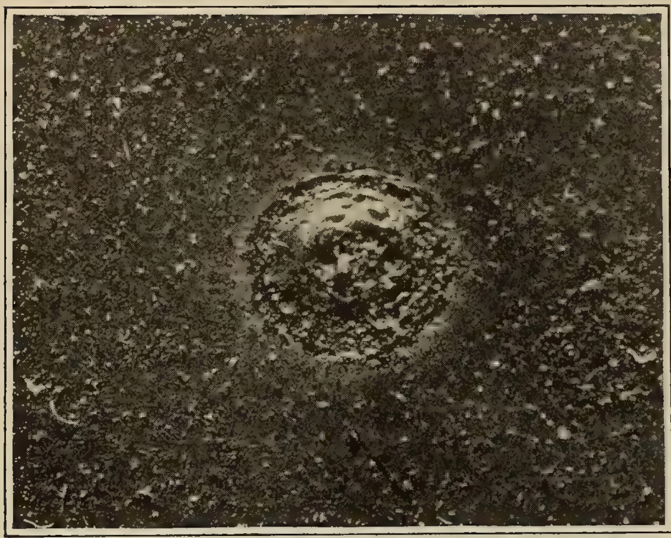
FIG. 3. DUST MAGNIFIED 20.7 DIAMETERS WHICH ACCUMULATES AROUND THE WORK DURING METALLIC ARC WELDING

plains the accumulation of iron dust in the welding room—or flatten out without fusion, the most common cause of poor welds. If the particles strike a fluid metal, they penetrate the fluid and solidify with the molten surface of the plate.

It is a well-established fact that the best welding is obtained with the shortest arc and the worst welding with the longest arc. It will be noted in Fig. 1 that the size of the electrode globule also increases with the length of arc, the best welding being obtained with the smallest globule. A small globule implies greater concentration of projected particles in the direction of the opposite fluid spot. In downward welding a large globule becomes elongated by gravity, the lower part of the hollow globule becomes thickened by downward flowing metal, the side walls become stretched and thinned, and particles are projected wastefully through the side walls at right angles to the arc. The globule as a whole frequently breaks away from the electrode and drops without

fusion on the plate. Electrode ends rejected by a welder and presenting the appearance shown in Fig. 1 constitute substantial evidence of ineffective long-arc welding. In upward welding a large globule tends to fall to one side or the other by gravity and prevents the efficient projection of metal.

Any material which serves to increase the melting point of the surface of an electrode must, in accordance with the stated theory, improve the conditions under which particles are projected from the electrode globule. The cup-shaped surface formed at the end of such an electrode will reduce the amount of indirect projection of particles to a minimum, and the increased stability of the arc will reduce the difficulty of manipulation of the electrode, since the length of arc may be varied over a greater range without interruption. It would appear that most of the coatings suggested for electrodes perform the function of cooling the surface of the electrode by vaporization and in some instances, owing to the rapidity



Courtesy of the Electrical World and the American Welding Society

FIG. 4. A HIGH MAGNIFICATION (16.7 DIAMETERS), OF A NUCLEUS OF METAL PROJECTED ON A COLD PLATE FROM AN INCANDESCENT ELECTRODE GLOBULE

of the action, remain in a fluid condition about the sides of the electrode globule. It should also be noted that since oxide (rust) has a higher melting point than steel, rust should not be removed from electrodes and that rusty electrodes will usually work better than bright clean ones. In many cases the outside layer of bare electrodes may be changed by drawing and heat treatment so that it has a higher melting point than the interior. The ideal electrode would have a high melting-point shell—tungsten for example—surrounding a lower-melting-point interior containing sufficient vapor-forming constitutents to eject metal constantly when heated.

The writer would suggest certain promising subjects for further study: First, a determination of the character of the vapor found in an electrode globule; second, a determination of the best surface material for electrodes, first cost and effect on the finished weld to be considered; third, the effect of welding in a reducing flame upon the character of the weld—the writer has found that such a weld is more ductile and reveals less formation of nitride; fourth, an investigation of the value of welding under water as in the case of ships, tanks, etc.; fifth, the use of materials other than steel in metallic arc welding.

PROTECTIVE RESISTANCES FOR HIGH-TENSION INSTALLATIONS.

CARBORUNDUM and similar materials behave as though they were a mixture of conducting and non-conducting bodies and their resistance decreases with increase of voltage. This allows their use as protective resistances in parallel on current transformers, trip coils, etc. With the occurrence of a pressure surge their effective resistance is reduced to a small per cent of its original value. The surge passes then through the short-circuit which is thus provided for it, after which the normal value of the protective resistance is restored so that the apparatus it protects can again function properly.

However, this characteristic of silicon-carbide resistances becomes undesirable when they are connected in series with pressure transformers, etc., when it is desirable to maintain the resistance at high voltage. By long rods or disk elements used for resistances to be connected in parallel it is possible to reduce the amount of this variation of resistance with applied voltage, but it is not possible to eliminate it altogether.

From a study of the silicon carbide resistances it was concluded that their decrease at high voltages is not due to temperature effect but rather to the nature of their composition. It was thought then that in order to eliminate this variation in resistance a metallic connection must be provided between the terminals. This condition and the necessity to secure high resistance makes it desirable to employ a coherent conducting mass as a core with which other materials, of higher or lower conductivity, can be combined. The oxides of certain metals possess such desirable properties. Copper oxide (CuO), for example has a conductivity of 400 ohms per ccm. and melts at a reasonably low temperature. The CuO is cast in form of rods which have high mechanical strength and which are coppered at the ends in order to obtain good electrical connection. Melting the CuO causes a considerable part of it to be reduced to C_2O which has a specific resistance of only 40 ohms per cm-cube. By adding other materials it is possible to vary the effective resistance over a wide range. Whether the resulting material is a compound or a solid solution has not been ascertained.

A series of tests showed that the resistance of carborundum elements offered to high-pressure surges was only one or two per cent of that obtained by a 2-volt d.c. bridge, whereas the high-voltage resistance of the new copper-oxide elements varied from 50 to 70 per cent of the values measured by the bridge. There are two reasons for the resistance drop in the latter case: 1. Sparking over the surface of the short-resistance bars provides a parallel circuit between terminals. 2. The resistances have a certain capacity which produces an appreciable displacement current at high frequencies. The resistance drop varies with the frequency and is therefore greater, the shorter the length of overhead line.

Experimental data given show that better protection is obtained by using the oxide resistances. A specific resistance of about 5,000 ohms per ccm. is obtained in oxide rods about 20 mm. diam. and 60 to 100 mm. long; higher resistances could be obtained by adding other materials. Another advantage of the new resistances is their high negative temperature-coefficient, which makes it possible for them to carry heavy loads without injury. For instance, a 12,000-ohm unit will carry 4.5 amperes without reaching a dull red heat; this means that the resistance must be diminished very considerably, otherwise the power dissipated in the resistance would exceed 250 kw., which would melt it at once. The high heat capacity of the resistances results in their being unaffected by heavy surges of current at times of short-circuit.—*H. Gewecke* in *Elektrotechnische Zeitschrift*, July 31, 1919.

USE OF ELECTRICITY IN THE ORANGE GROWING INDUSTRY.

ELECTRIC pumping is but one feature of the use of electrical energy in the orange industry. The orange packing-house is today operated entirely by electricity. The fruit is washed by electrically driven washers. Then the brand label is placed on it by another electrical device. The orange then finds its way into the electric sorter, in which the oranges are graded for the market. Even the boxes are made and nailed up by electrical machinery, and in some of the largest packing houses there are many labor and time-saving devices, which get their power from electric motors.—Abstracted from *Electrical Review.*

The Ultra-Rapid Cinematograph

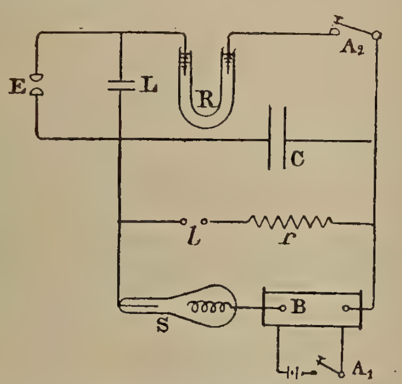
Taking Pictures at the Rate of 20,000 Per Second

At a recent session of the French Academy of Sciences, Dec. 1, 1919, a report was made by Messrs H. Abraham, E. Bloch, and L. Bloch, stating that they had been able to register moving picture images of the remarkably high frequency of more than 20,000 per second. While the applications of such a system of cinematography are limited to very special cases, they nevertheless possess yery great scientific uses as will appear in the following statement by the authors:

In the study of certain very rapid movements and in particular in certain problems of ballistics, the analysis of the phenomena cannot be undertaken except by the cinematographic method. But the latter requires in such cases an extreme degree of rapidity, as much for example as 20,000 or even 50,000 photographs per second. . . .

Much important research has already been conducted along this line. We shall here confine ourselves to citing that by M. Bull with which our own researches are connected. At the Institute Marey M. Bull succeeded in making cinematographs at the rate of 3,000 photographs per second. He operated with the objective uncovered and with a continuous movable film, illuminating the object by a series of sparks proceeding from the condensed discharge of a Ruhmkorff coil; this is the same device already employed by Boys for taking instantaneous photographs of projectiles.

The device employed by us during the past year enables us to raise the frequency to a very high degree. The principle consists in charging up to about 5,000 volts a small Leyden



ELECTRICAL CONNECTION OF THE ULTRA-RAPID CINEMATOGRAPH

jar, which is immediately discharged in a discharger, being then freshly charged from a source of high tension electricity (12,000 to 15,000 volts). The regularity of the discharge is secured by a vigorous blowing of the sparks, the effect of which is to prevent the disruptive spark from passing to the arc.

In default of a continuous current or of a battery of accumulators, one may employ as a high tension source a strong condenser which has been previously charged and forms a reservoir of energy. Or one can also make use of the secondary circuit of a transformer in which the primary tension has been abruptly established.

In the diagram condenser C, insulated for 20,000 volts, has a capacity of the magnitude of a demi-micro-farad. It is given a charge of from 12,000 to 15,000 volts, by means of a transformer or else by a Ruhmkorff coil B, provided with a thermo-ionic valve or with a Villard valve, S. The condenser C is protected by a tension-limiting discharger l, provided with a series resistance in r. An electrometer (not represented in the diagram) is likewise shunted in thus permitting us to follow the voltage of the charge.

The capacity of C is sufficient to supply the Leyden jar L a great number of times without its own potential being perceptibly lowered. In order to avoid any disturbance proceeding from the coil B during the taking of the photographs, it is advisable to cut the primary of the said coil with an interrupter A_1, which opens automatically at the moment of the photographic operation. At the same instant the interrupter A_2, placed in the circuit of discharge, is suddenly closed. Furthermore, since the supply of energy from C is limited, it is well to provide a third interrupter (not shown in the diagram) which cuts the circuit of discharge at a convenient moment, for example, after the taking of from 100 to 200 photographs. The small Leyden jar L, having a capacity of less than one thousandth of a micro-farad, is charged through an adjustable liquid resistance R. It is the latter which determines the value of the average current yielded by the intermittent discharges, thus determining the frequency of the sparks.

The circuit of discharge EL is very short in order that the sparks may be extremely brief in duration. These sparks which are extremely photogenic, serve to illuminate the movable object, and since the durations of the illuminations are of the magnitude of one millionth of a second, the photographs are practically instantaneous. The discharger E is formed between aluminum hemispheres which are thoroughly cleansed with fine emery cloth before each operation; the distance of discharge is about one mm.

We are thus able to obtain, without difficulty, a spark of frequency exceeding 50,000 per second. The photographs must be taken upon a sensitive film having a very rapid movement. Our first tests were made with disks covered with gelatinous-bromide paper 20 cm. in diameter, driven by the shaft of a ventilator motor having 6,000 revolutions per minute. Better results, however, appear to be obtained by rolling a sensitive film around a cylindrical drum in rapid rotation according to the method of M. Bull, who has thus obtained remarkable moving pictures of the motion of projectiles.

We may sum up the matter by the statement, that thanks to the employment of continuous discharges broken up by blowing, it is now easy to take moving pictures at a rate of speed exceeding 20,000 photographs per second.

MOTION PICTURES IN SWITZERLAND.

Motion pictures have not, as yet, penetrated to all sections of Switzerland, but reports show that progress is being made from day to day. The war had a very stimulating effect upon the industry, all the belligerent countries having used this means for propaganda work; and while no one can state what effect this propaganda had upon individual opinion regarding the war, it has had the result of converting the people to this form of amusement. Compared with other countries and considering the population, Switzerland possesses today a relatively small number of motion-picture theaters and none at all of any great seating capacity. As a result, the smaller houses are very well patronized.

The production of motion pictures has not been undertaken to any extent in Switzerland, there being at the present time but one concern and it is not important. However, several of the large French and German producers have, at various times, utilized Swiss mountain scenery for staging scenarios. Of the films imported into Switzerland about 60 per cent are of American manufacture, the remainder coming from Germany, France and Italy. Films coming from France are, in many instances, reproductions of American films made at the French agencies of the American producers.—Abstracted from *Commerce Reports.*

The Breakdown Voltage of a Spark Gap*

Effect of Temperature and Pressure

By L. B. Loeb and F. B. Silsbee

THE investigation here described was conducted at the Bureau of Standards for the National Advisory Committee for Aeronautics, in order to determine the necessary minimum potential for causing sparks to pass in a gasoline engine whose compression ratio was known and in which the temperature of the gases before ignition could be estimated.

According to the simple theory (J. J. Thomson, Conduction of Electricity Through Gases; Townsend, Electricity in Gases; and Peek, Transactions of the American Institute of Electrical Engineers, 1910-1916) the sparking potential depends solely on the density of the gas between the electrodes for a given fixed pair of electrodes, *i.e.*, on the total number of molecules between the electrodes. This has been invstigated over a considerable range of pressures, spark distances, and forms of electrodes by numerous observers, but only three investigators have studied the effect of temperature, and then only over a limited range. They all found that the sparking potential depended solely on the density of the gas over the range studied.

In the study of airplane spark plugs it seemed advisable to determine whether this law held for pressures and temperatures which might occur in the cylinders of a high compression engine just before the ignition of the charge. In airplane engines the maximum compression pressures under normal conditions range from 90 to 130 pounds per square inch with temperatures up to 300° C.

APPARATUS.

The experiments were conducted as follows: An ordinary ⅞-inch Titan A. C. porcelain plug was screwed into a steel bomb about 25 cm. (10 inches) long having the design indicated in Fig. 1. There was a thick glass window opposite the sparking terminals when the plug was screwed in position. A high-pressure air tank connected to the bomb through suitable valves served to regulate the air pressure to any desired value. Temperatures were measured by a Pt, Pt-Rh thermocouple, B. S. W5, which was inserted in a steel tube sealed at one end with walls ½ mm. (0.020 inch) thick. This was screwed into the bomb so that its inner end was within 1 cm. of the sparking terminals of the plug. The bomb was placed in a cylindrical electric resistance furnace and packed with asbestos wool, so that only the porcelain insulator was exposed at one end, while the window projected out about 5 cm. (2 inches) beyond the other end.

Sixty-cycle voltage was supplied through a step-up transformer having a ratio of 200:1 and applied between the central electrode and the bomb. A resistance of 220,000 ohms was put in series with the plug to avoid an excessive current and consequent burning up of the terminals when the spark passed. The voltage was read on a voltmeter connected to the low-tension side of an auxiliary step-down transformer. The passage of the spark was made evident both by the kick of the voltmeter and by the appearance of the spark in the bomb. Ionization was provided for by the use of a half milligram sample of radium in most of the experiments, while in some a 50-mgm. sample, placed just below the electric furnace, was also used. This ionization served to eliminate the complicating effect of spark "lag" and made the readings much more consistent and reliable. No striking difference in the readings could be noticed with the two different samples.

The tests were run on three Titan plugs: No. 1 had the regular terminals of Ni-Ma wire 1.3 mm. (0.051 inch) in diameter set at right angles and separated by 1.8 mm. (0.071 inch); No. 2 was a Titan plug with similar terminals 3.13 mm. (0.123 inch) in diameter rounded at the ends, separated by 1.2 mm. (0.047 inch); No. 3 was a plug like No. 1 but with a distance of 2.2 mm (0.086 inch) between the wires. In each case the spark passed between the cylindrical surfaces of the wires near the point of closest proximity.

PROCEDURE

The readings were taken as follows: The temperature was run up to the desired value and held constant from 15 minutes to half an hour. There were fluctuations at the higher temperatures of as much as 10 degrees either way so that a mean temperature was chosen as representing the true conditions. The breakdown voltage of the gap was then determined by at least 10 trials for each pressure. The pressure was increased in steps of 10 pounds per square inch. The pressures were read by two small pressure gages whose ranges were from 0 to 100 pounds per square inch. The spark potentials were read to as high a pressure as it was possible to obtain without the sparks passing over the outside of the insulator. Then the

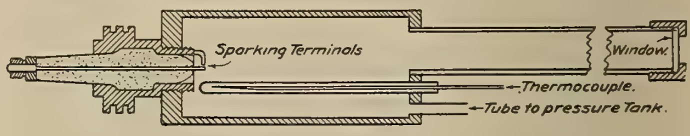


FIG. 1. STEEL BOMB IN WHICH SPARK PLUGS WERE TESTED

pressure was reduced in steps of 20 pounds and readings again made. As a whole the return readings checked the first readings well. This can be seen from the plots where maximum sparking voltage is plotted against the pressure for each temperature. As the voltage which could be used without sparking over the outside of the porcelain was about 19,000 volts, no voltages were measured above this. The pressure range over which the measurements could be carried out started from 60 pounds at room temperature and increased until at 200° C., or thereabouts, pressures of 100 pounds could be used.

From then on the pressures were limited with increasing temperatures by a new phenomenon which may have been caused by electron emission from the hot terminals at high voltage. Under these conditions the spark was replaced by a sort of purple brush discharge (corona) which came on gradually as the voltage was increased.

It was at first thought that this glow discharge might be an important factor in causing ignition trouble. Further measurements were therefore made in the same apparatus but with a Bosch D-C magneto as a source of voltage. With this arrangement no brush discharge could be detected although the observations were carried to 760° C. Above 600° C. the electrical conductivity of the porcelain insulator was great enough to prevent the magneto from sparking at the higher pressures, but there was no sign of brush discharge under any conditions. It is probable that a certain time is required for such a discharge to form and that the very sudden application of voltage produced by the magneto does not admit of this.

RESULTS.

The curves plotted between maximum sparking potentials in kilovolts and pressure in atmospheres may be seen in plots 2, 3, and 4. The results represented by all these curves, except the one for low temperature measurement with the larger terminals could be repeated consistently. It is possible that a

*Abstracted from Report 54 of the National Advisory Committee for Aeronautics.

stronger source of ionization should have been provided, and the voltage increased still more slowly in this case. The slight curvatures of the lines may be due in part to the gages, since no calibration corrections were applied. The direction of the curvature is the same as that noted by other observers.

The data given in the curves were analyzed by first reading from each of the curves the pressure corresponding to a given voltage, say 10,000 volts. From this pressure and the temperature pertaining to the curve, the relative density of the gas is then computed by the formula.

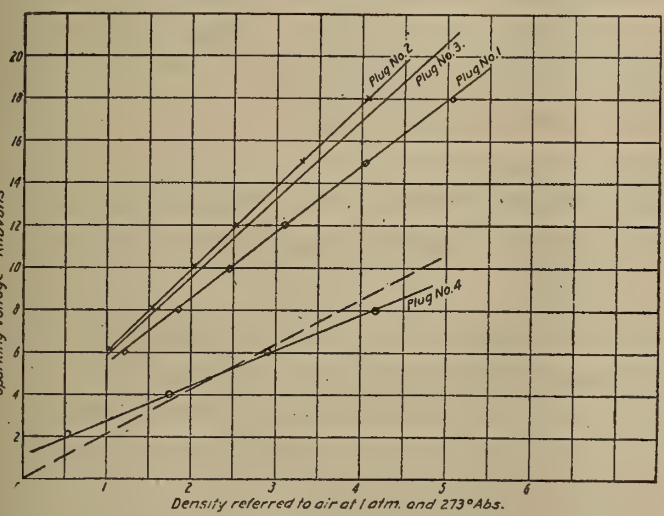
$$\rho = \frac{\delta}{\delta_0} = 273 \frac{P}{T}$$

where δ_0 is the density at 1 atmosphere and 273° absolute, P is the pressure in atmospheres, and T the absolute temperature

Temperature Abs.	Density at	
	10,000 volts.	8,000 volts.
300°	2.51	1.83
383°	2.46	1.80
455°	2.27	1.80
553°	2.38	1.78
700°	2.59	1.96
Mean	2.45	1.83

in degrees centigrade. This was done for six different voltages on each plug. The table above gives the results of plug No. 1 at 10,000 and 8,000 volts, and is typical of the other data. It is evident that the densities thus obtained are constant within a few per cent over the entire range and show no systematic change with temperature or pressures.

It may therefore be concluded that the breakdown voltage is a function of the gas density only. To determine the form of this function the average values of density obtained as described above are plotted against the corresponding voltage in Plot 1. The curves thus obtained show that the breakdown voltage is a linear function of the density but is not propor-



PLOT 1

tional to it. The data can be represented by the following equations:

Plug No. 1	$E = 2.2 + 3.1\rho$
Plug No. 2	$E = 1.8 + 4.0\rho$
Plug No. 3	$E = 2.4 + 3.4\rho$

Where E is the sparking voltage in kilovolts and ρ is the density relative to air at atmospheric pressure and 0° C. The constants in these equations are of course dependent upon the shape and spacing of the electrodes, and would be smaller for the case of the shorter 0.5 mm. (0.020 inch) gaps used in spark plugs.

In addition to the measurements with alternating current described above, a second series of tests was made, using a Bosch D-6 magneto as the source of e. m. f. and a special crest voltmeter equipment[1] to measure the breakdown voltage.

This equipment consisted of an Albrecht electrostatic voltmeter connected in series with a G. E. kenotron (electric valve) as shown in Fig. 2. This valve permits current to flow when the heated filament F is negative with respect to the relatively cold anode A, but allows no current to flow in the reverse direction. Consequently, a negative charge accumulates on the insulated conductor, formed by the anode and the case of the electrometer, of such amount that when the sparking electrode and voltmeter needle are at their greatest positive potential the filament and anode are at the same potential, and there is no tendency for further charging. During the rest of the time the needle of the voltmeter is near ground potential, but the rectifying effect of the kenotron prevents the charge from leaking off. Consequently the meter comes to a steady deflection which measures the maximum positive voltage applied.

Runs were made with this apparatus at temperatures of 460° C. and 520° C. up to pressures of 150 pounds per square inch, using a Champion (Toledo) plug No. 4 with ×-bend electrodes set with the usual spacing of 0.5 mm. (0.20 inch). The results

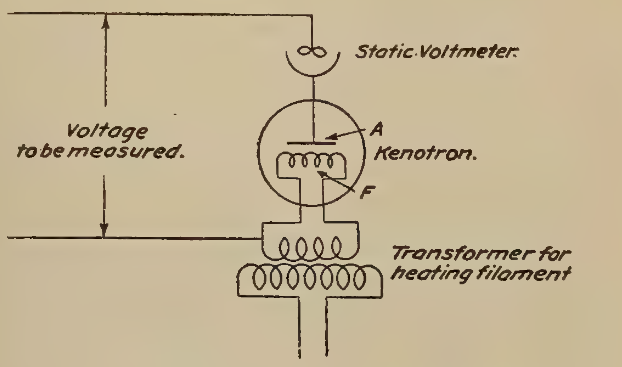


FIG. 2. APPARATUS USED TO MEASURE THE BREAKDOWN VOLTAGE

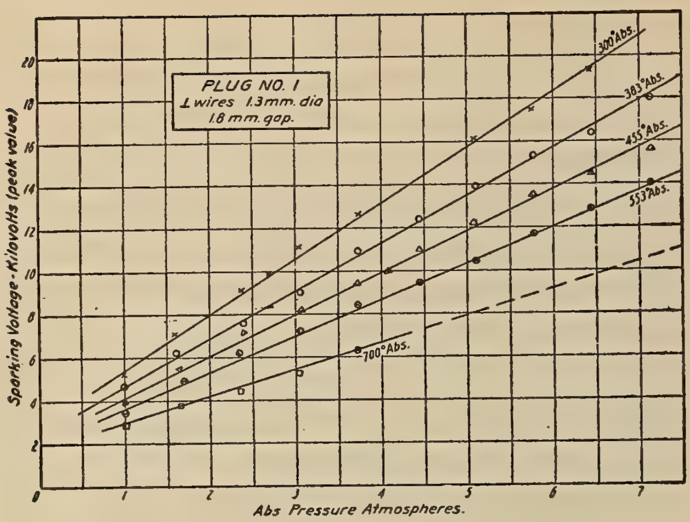
as obtained are plotted in Plot 5 and the combined data from these curves are plotted against relative density in Plot 1, giving a line whose equation is

$$E = 1.1 + 1.7\rho.$$

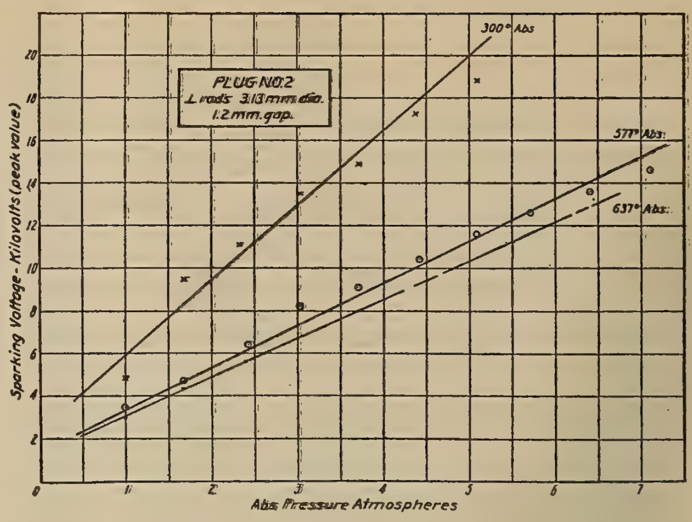
These measurements with the magneto and crest voltmeter showed the presence of a further complication due to the fact that the heat of the spark raised the temperature of the electrodes very materially. This in turn heated the gas near them so that the discharge occurred through gas which was decidedly less dense than the surrounding atmosphere. This was indicated by the fact that at first starting the magneto the voltmeter showed a relatively high voltage (in one case 4,100 volts), which decreased gradually for nearly a minute, after which it remained constant at a much lower value (2,350 volts). The time required for the change implies very strongly that it is a purely thermal effect rather than any ionization due to the preceding sparks, since the latter effect would be almost instantaneous. In the case of a spark plug in an engine cylinder, the central electrode, being insulated thermally as well as electrically by the core, is much hotter than the incoming charge and consequently this effect may be present to some extent.

As a check upon the laboratory data measurements were

[1] Sharp, C. H., Electrical World, 69, p. 556, 1917.



PLOT 2



PLOT 3

also made in a Hall-Scott A-5 aviation engine having a compression ratio of 4.2:1. Owing to the late closing of the intake valve and the advance of the spark, the actual ratio of cylinder volume at intake to that at ignition was only 3.2:1. If it can be assumed that the charge in the cylinder is at atmospheric pressure and the temperature at the closing of the intake valve, then the relative density at ignition will be 3.2. Plug No. 4 was run in this engine firing from Dixie "88" magneto. The crest voltage as measured by the kenotron was found to be 5,950 volts. Measurements with a calibrated spark gap having 1 cm. spheres indicated 4,500 volts. The voltage predicted for this density from Fig. 2 is 6,400 volts.

In comparing these results it must be borne in mind that the crest voltmeter loses its charge very slowly, so that it really indicates the highest peak occurring during two or three minutes preceding the reading. The parallel spark gap, on the other hand, is adjusted to fire about half the time and probably gives more nearly the average crest voltage. It appears, therefore, that the results obtained in the laboratory are in substantial agreement with those found on the engine, and that the linear relation between voltage and density may be safely applied to ignition circuits.

It will be noted that the results shown in Plot 2 can be represented roughly by a straight line through the origin, such as is shown dotted, and which indicates a direct proportionality between the sparking voltage and density. This relation will be found useful in cases where the voltage is known at some one density and it is desired to estimate it for another density not too widely different. It is unsafe, however, to use this law of direct proportionality to extrapolate over a long range from the sparking voltage at normal atmospheric density to that at very high density.

CONCLUSIONS.

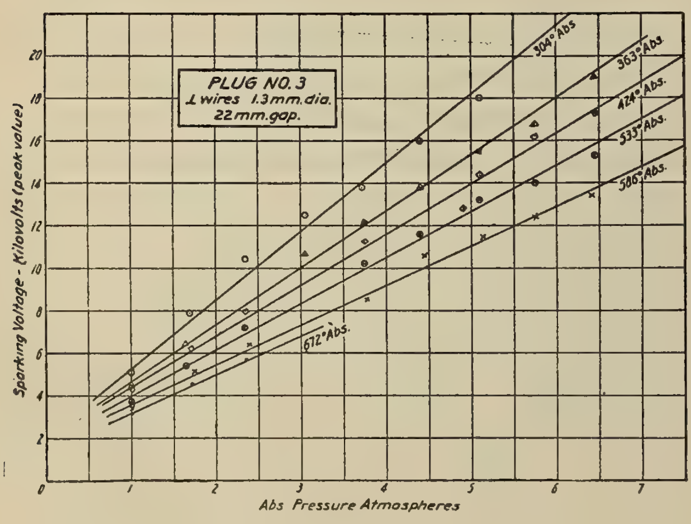
These experiments confirm the relation that the breakdown voltage of a spark gap depends only upon the density of the gas and varies with pressure and temperature only as they effect the density. This relation is found to be valid up to 800° C. and 8 atmospheres pressure. Both the pressure and temperature of the charge in a gasoline engine increase very greatly during the compression stroke, but the sparking voltage can be computed from the linear relations shown in Plot 2 without a knowledge of these variables separately, since the density is determined solely by the original density and the compression ratio. For small changes in density, the assumption that the voltage is proportional to the density may be made.

With the sudden discharge from an ignition coil or magneto a disruptive spark is produced even at temperatures where a 60-cycle voltage would produce a brush discharge.

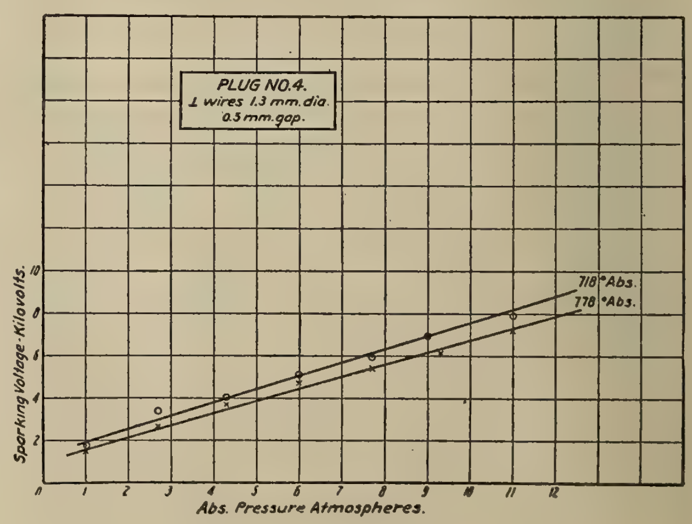
The voltage required for a spark plug set at 0.5 mm. (0.020 inch) in an aviation engine of moderate compression is of the order of magnitude of 6,000 volts.

LARGEST ELECTRIC HATCHERY

THERE is an electric hatchery at Artesia, Cal., which is claimed to be the largest in the world. It has a capacity of 100,000 eggs and produces 30,000 chicks per week.



PLOT 4



PLOT 5

Fatigue Phenomena in Metals*

Summary of Available Facts and Theories Relating to Fatigue Failure and a Discussion of Some Unsolved Problems

METAL parts of machines, such as springs, shafts, crank-pins and axles, occasionally fail suddenly while only subjected to conditions of ordinary service. Not only does failure occur suddenly, but the part about to fail shows no ordinary evidence of weakness. The broken parts when examined are seen to be broken off short, and without general distortion, even though the material may show high ductility in ordinary tests. Such failures are found only in parts subjected to stress repeated many times—to "vibration," as it is sometimes stated—and the phenomena which are involved in the final failure of metal through oft-repeated loading are known as "fatigue" phenomena of metals.

The phenomena of fatigue failure have recently given rise to some perplexing problems in connection with the design and service of air-plane-engine crankshafts, the hulls of steel ships, axles and shafts in railway cars, motor cars and trucks and other machine parts. The question whether structural parts subjected to repeated stress are in danger of fatigue failure has been discussed at considerable length. The danger of fatigue failure seems to be an unimportant factor in determining the safety of structural parts, with the possible exception of parts subjected to reversal of stress. The reason for this is probably found in the relatively small number of loadings which most structures are called upon to withstand, and in fact that most of the loadings are below the maximum working value. On the other hand, the danger of fatigue failure is a major factor in determining the safety of many machine parts.

The problem of fatigue of metals engaged the attention of engineers seventy years ago, in connection with car axles and members of iron railway bridges. It was early recognized that high stress tends to cause, or at least to hasten, fatigue failure, and about 180 Wöhler's famius investigations were undertaken to determine the relation between intensity of fiber stress and the ability of materials to resist fatigue under repeated stress. Wöhler's tests occupied some eleven years, and remain to this day the most thorough tests on record. Wöhler investigated metals under direct tension, under bending, and under tension (shear). For some of his tests the stress varied from zero to a maximum, and for others the stress was reversed.

Following Wöhler the famous Bauschinger published a series of conclusions on fatigue, and various other investigators, notably Gerber, and Weyrauch and Launhardt, gave early interpretations of the experimental results of Wöhler and Bauschinger.

In these earlier experiments several facts seem noteworthy. The prime object of the investigators was to deduce laws of fatigue for railway bridges and car axles. The problem of fatigue in high-speed machine parts had not then appeared. These investigators carried their tests far enough to cover the number of repetitions required by the structures of their day and assumed that having done so they had established an endurance limit. Reading their conculsions carefully, the statement does not seem to be made that material which passed their tests would stand an *infinite* number of repetitions. The term generally used is "indefinite" or "very large," and the number corresponding is from ten to fifty millions. For the problem which they investigated their tests seem to give safe guides for practice, but today, with the advent of modern high-speed machinery, some parts of which must be as light as possible, and the extension of the fatigue problem to such members as the cranks and the connecting rods of gas engines and the shafts of steam turbines, the number of repetitions of stress which a machine member may be called upon to undergo is very much increased. This fact is illustrated by Table 1, which gives a statement of the approximate service required from various structural and machine members.

Investigations have been made in recent years by Howard, Stanton, Basquin, Smith, Eden, Rose and Cunningham, Kommers, Mason, Moore and Seely, and others. The efforts of these investigators have been directed toward the study of moderin materials, refinements in methods of testing, and interpretation of results. The limits of actual tests have not been extended to modern requirements, and the problem still remains of obtaining test data for much longer endurance of fatigue than was contemplated by Wöhler. Under the most favorable conditions conceivable such data will be obtained very slowly, and meanwhile there must be faced the problem of determining safe stresses for very large numbers of repetitions by extrapolation from previous test results.

Table 1. Approximate service required of various members of structures and machines subjected to repeated stress.

Part of structure or machine	Approximate number of repetitions of stress in the "lifetime" of the structure or machine
Railroad bridge, chord members	2,000,000
Elevated-railroad structure, floor beams	40,000,000
Railroad rail, locomotive wheel loads	500,000
Railroad rail, car wheel loads	15,000,000
Airplane-engine crankshaft	18,000,000
Car axles	50,000,000
Automobile-engine crankshaft	120,000,000
Lineshafting in shops	360,000,000
Steam engine, piston rods, connecting rods and crankshafts	1,000,000,000
Steam-turbine shafts, bending stresses	15,000,000,000

MACHINES FOR TESTING FATIGUE STRENGTH.

Fatigue tests cannot readily be carried out with ordinary "static" testing machines. It is, of course, possible to repeat loadings on a test specimen in such a machine, but the process is very slow. Such a machine equipped with an ingenious automatic arrangement for applying and releasing load was used by Van Ornum in fatigue tests of concrete in compression, but the time required for even a hundred thousand cycles of stress was very great.

A very simple repeated-stress testing machine acts by the application and removal of a weight to the end of the long arm of a simple or compound lever, the specimen carrying load at the short arm. Such a machine was used by Berry in fatigue tests of concrete in compression. In a machine of this type the load must be applied slowly, else there will be inertia forces set up by the impact of the weight as it is let into place.

A common type of repeated-stress testing machine is one in which a calibrated set of springs resists the tensile, compressive, flexural, or torsional stress set up in the specimen, and the deformation of the calibrated set of springs gives a measure of the force or moment acting on the specimen. Fig. 1 diagrammatically illustrates this type of machine which was used by Wöhler and has since been used by many other experimenters. The Upton-Lewis machine is of this type and extensive use was made of it in torsion tests carried on by McAdam. This type of machine permits a fairly high rate of repetition of cycles of stress, and machines which have been run at 1,000 repetitions per minute have given results apparently trustworthy.

*Reproduced from the *Journal of the American Society of Mechanical Engineers*. A progress report of Committee on Fatigue Phenomena in Metals which is acting under the joint auspices of the Engineering Foundation and the Division of Engineering of the National Research Council.

The most common type of machine for reversed bending stresses uses a circular specimen acting as a rotating beam. This type was used by Wöhler, and also by many later investigators. Fig. 2 illustrates such a machine. The specimen is in form of a bar of circular section, to which bending stress is applied by weights. The specimen is rotated by means of a pulley. At any instant the outer fibers are subjected to a stress varying from tension on one side to compression on the other, and the fiber stress at any point passes through a cycle of reversed stress during each revolution. As shown, the specimen is loaded at two symmetrical points of the span, and between these two points the extreme fiber stress is constant for each element along the bar. This type of machine permits high speed of reversal of stress, speeds up to 2,000 r.p.m. having been successfully used.

British experimenters have used repeated-stress testing machines in which varying stress was applied to a specimen by means of the inertia of reciprocating parts. Fig. 3 shows such a machine, which can be used at high speeds. However, the speed must be very closely controlled, as the inertia forces vary with the square of the speed. Moreover, friction on the guides causes some slight uncertainty as to the magnitude of stress set up at each stroke of the crank.

A repeated-stress testing machine depending on centrifugal force to produce cycles of stress is shown in Fig. 4. It is evident that as the eccentric weights revolve the specimen will be placed alternately in tension and in compression. This machine has been used by J. H. Smith. Its characteristics are much like those of the inertia type; in fact, it is a special form of inertia machine.

A type of machine used by Arnold and later by other experimenters is shown in Fig. 5. In this machine a specimen is repeatedly given a certain deflection. Usually this deflection is sufficiently large to stress the material well beyond the yield point, and no very definite stress can be computed. This machine is used mainly for short-time tests.

Another short-time-test machine uses the repeated impact of a small hammer. The claim is made that impact loading emphasizes local flaws better than a load which is more gradually applied, and that it *indirectly* gives a better index of fatigue strength. Data, however, are lacking to prove or disprove this claim.

Various repeated-stress testing machines have been constructed in which the cycles of stress were set up by the action of an electromagnet energized by alternating current. Usually the stress was measured either by the deflection of a spring or by the deformation of a standard test bar attached to the specimen. The speed of such a machine, however, is usually so high that there seems to be some uncertainty as to whether the successive waves of stress pass through the specimen without interference.

While the microscope can hardly be classified as a testing machine, it has, nevertheless, been of such vital importance in studying fatigue phenomena that it may well be mentioned in this place. Space will not permit of a detailed description of the methods employed in the microscopic examination of metals, but the process involves polishing a small area of the metal, etching the surface with some reagent to bring out the lines of the crystalline structure and examining and photographing the surface through a microscope, the surface of the metal being illuminated by means of a reflected light.

THE PHENOMENA OF FATIGUE FAILURE.

A fatigue failure of a metal, whether it occurs in a test specimen or in a machine part, is characterized by suddenness, lack of warning, apparent brittleness of material, and, in many cases, a fracture with a crystalline appearance over a part of its surface.

This crystalline appearance led to the old theory that under repeated stress metal "crystallized," changing from a ductile "fibrous" structure to a brittle "crystalline" one. This theory, however, has been quite thoroughly demolished as a result of study of the structure of steel under the microscope. As revealed by the microscope the structure of all metals used for structures and machines is crystalline, any "fibrous" structure being caused by inclusions of non-metallic impurities (for example, slag in wrought iron). Microscopic examination of metals under stress shows no change of the general scheme of internal structure, but under sufficiently heavy stress there appears gradual breakdown of the crystals in the structure.

When a ductile metal is deformed cold, the first deformation occurs in the particular grains which either take the most stress or have the lowest elastic limit. Deformation takes place by the slipping of one portion of the grain with reference to other portions. This slipping is shown by the appearance of lines called "slip bands" or "slip lines" extending across crystals and indicating planes of cleavage. As the load is increased deformation proceeds and other slip bands are formed, the law being that the most easily deformable grains

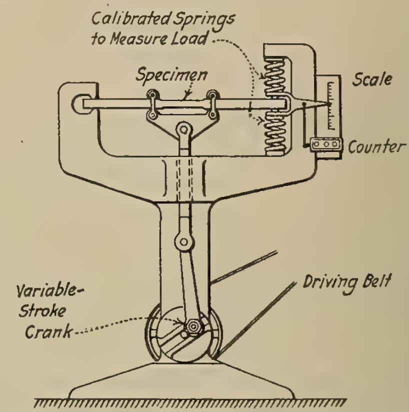


FIG. 1. A TYPE OF REPEATED-STRESS TESTING MACHINE

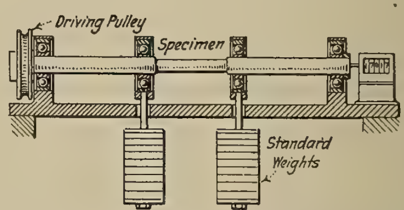


FIG. 2. TYPE OF MACHINE FOR DETERMINING REVERSE BENDING STRESSES

first show slip bands. Gradually the most favorable planes of slip are exhausted, and further slippage can take place only with the addition of more load.

The failure in ductile metals subjected to repeated stress takes place with substantially no general deformation. There is, however, considerable local deformation over microscopic areas, evidenced by the appearance of many slip bands on a polished surface of the metal after the application of repeated stress. These slip bands appear after a small number of reversals of stress with relatively large loads, and may not appear at all with slight loads. The slip bands may first appear either in the interior of a grain or at the grain boundary. As the number of applications of stress increases more slip bands appear, and those first appearing usually lengthen and widen. Under the microscope and with normal illumination the general surface becomes blacker as the number and width of the slip bands increase. In ductile metals fatigue failure is almost exclusively through the grains themselves rather than at the grain boundaries, and the first slip bands to appear do not necessarily form a part of the final path of rupture. Failure seems to take place by the uniting of slip bands into cracks. When the first grain develops a crack extending across its entire width, added stress promotes the extension of this crack into adjacent grains on both sides, although the orientations of these grains may be and usually are such that the crack must extend itself at an angle to that in the initial grain. The general tendency is for these

slip bands to follow the lines of cleavage of the particular grain in which they occur. Often incipient fracture is found in many grains adjacent to the final path of rupture, indicating that had rupture not taken place where it did, it would have soon taken place in some other adjacent part.

Such observations by means of the microscope indicate that *localized deformation* is the primary cause of fatigue failure in ductile metals, but it does not necessarily follow that the formation of one slip band under repeated stress will indicate eventual fracture if the loading is continued; one grain may appear to have a greatly reduced elastic limit because of in-

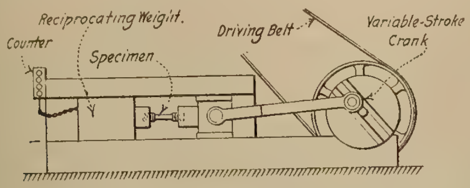


FIG. 3. BRITISH FORM OF REPEATED-STRESS TESTING MACHINE

ternal strains or peculiarly unfavorable orientation. It is not certain that there is a limiting load below which fatigue failure will never take place.

Materials classified as brittle have very little permanent deformation under static stress, and under repeated stress the progressive fracture of brittle material might take place, not by slipping within crystals, but by tensile fracture of crystals. There has been practically no study made of the fracture of brittle materials under repeated stress, and it would be instructive to have tests carried out on brittle amorphous materials such as fused silica and on brittle crystalline materials like marble or tungsten. It is gradually being recognized that the breaking load of a specimen is a complex matter, and depends, among other things, on the time of application of the load. Mere duration of static loading, however, does not have an effect at all comparable with repetition of loading in reducing the breaking load. It seems evident that the distribution of stress in some brittle materials is very much less uniform than in ductile materials, and that fractures in brittle materials start on areas of high stress, whereas in ductile materials the high stresses are relieved by local yielding. A more complete understanding of the mechanism of rupture in brittle materials would doubtless be of great value.

When the action of metal under repeated stress is considered from the view point of the internal strains and accompa-

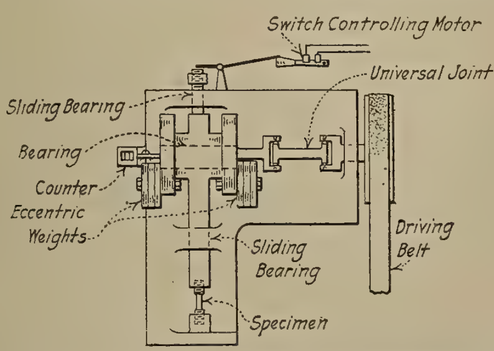


FIG. 4. SPECIAL FORM OF REPEATED-STRESS MACHINE

nying stresses in the material, a radical difference is seen in the behavior of material under static load and under repeated load. In a general way we may consider any structural or machine part as subjected to static conditions if the load on it is applied gradually and is not repeated more than a few hundred times; the part may be considered as subjected to fatigue if the load on it is applied, say, one hundred thousand times or more; and for intermediate conditions of loading the phenomena characteristic of both kinds of loading would be present.

We must look upon steel as filled with a multitude of minute flaws. These flaws are developed in the solidification of the material. In static testing, steel under stress of about half its ultimate strength passes into semi-plastic condition, in which there is a gradual flow of the material. Under such conditions the small flaws have almost no effect upon the flow or upon the static strength. When steel is loaded to moderate stresses the yielding is almost entirely elastic, but in general a small portion of it is inelastic, energy being taken up by the steel itself. If the specimen can be loaded a great number of times without heat loss its temperature will increase. If it is set vibrating in a chamber free from air it will stop vibrating in a short time, due to the absorption of energy. In such cases the stress-strain curve appears to be straight and the curve for the removal of the load may be practically identical with that for the application of load, but still these other effects show loss of energy in the steel itself.

This loss of energy is doubtless due to small displacements at these flaws, which are not reversible. Under alternate loadings these displacements are made back and forth. Energy is continuously being absorbed in the location of these small flaws, and it is perfectly natural that they should increase in size. We must look upon these extensions of the flaws as occurring in a great many parts of the steel. If the stresses are small the increased size of these flaws is practically negligible, but if the stresses are larger the increase is rapid, and later on in the history of the piece under test, very rapid, and

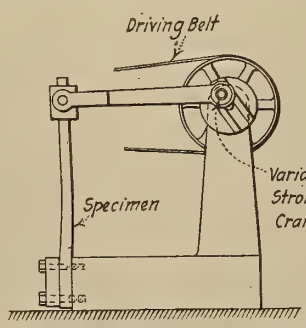


FIG. 5. SHORT-TIME REPEATED-STRESS TESTING MACHINE.

finally the strength of the piece is terminated when a sufficient number of these flaws have connected so as to form an area of very great weakness.

For static loads all the above is of little consequence with a ductile metal; but it is of consequence in the case of a brittle metal like cast iron, which has a remarkably low strength in tension in comparison with its compressive strength. Ductile metals may be considered as having a very high value for cohesion with a rather low coefficient of friction—or whatever corresponds to that—so that these metals begin to slide on diagonal planes without actual fracture under high local stress.

When a ductile material is loaded it may be subjected to stresses whose average values for small areas are not very different for parts that are a tenth of an inch apart; but there is a multitude of tiny spots whose fiber stresses are 2, 3, 4 or 10 times the average value. This holds so long as elastic conditions obtain. As the applied stress increases some of these stresses increase in like ratio, but not in like increments. At moderate applied stresses these special stresses reach inelastic conditions and slipping occurs. If the average stress is now entirely removed, we may assume that the unloading takes place in a similar manner. The small spots unload first in an elastic manner, but at a different rate than the remainder of the material. They will unload approximately at the same rates as they used in taking stress, namely, 2, 3, 4 or 10 times the normal rate. For the unloading they have about twice the range of stress that they had in the loading before inelastic action is set up. Some of them will reach the opposite limit and slip part way back again, while some of

them may not be subject to this return slip of inelastic action, but will retain in the unloaded state a stress distribution of the opposite kind. Either of these actions will give rise to hysteresis and to slight change of dimensions, usually, however, too small to be detected.

In all of the foregoing the main parts of the material have not been subjected to stresses which give inelastic action. If the loading is repeated without reversal, the spots that slipped on the first unloading will be subjected to further slipping both on loading and on unloading, but the areas that suffered no slipping on the first unloading should show no further inelastic action unless the loading is reversed. If the loading is reversed, however, all the particles that slipped in the first loading will slip on the reverse loading, so that with repetition a larger number of spots undergo this slipping action than is the case with loading which is not reversed. This explains the shorter life under reversed stress than under repeated stresses in one direction only.

If the fractural surface of a "rotating beam" specimen made of ductile metal and broken by repeated stress is examined, it is usually seen to be made up of two parts: (1) near the extreme fibers there is a dark surface with a dull, lusterless appearance, while (2) the remainder of the surface has a bright crystalline fracture. If these are examined more carefully it is found that their principal difference is in the size of the small flat surfaces that constitute the fracture. The center portion of the area has comparatively large surfaces, giving a crystalline effect, while the dull gray portion has very small surfaces of fracture.

An explanation of this is that the flaws in the outer portion of the surface have connected to form an annulus, whose rugged face is roughly at right angles to the axis of rotation. This has doubtless occurred slowly, and has started from many centers, thus giving the rough face. After this slow growth of flaws into an annular fracture has been accomplished the specimen has become very weak and the stresses have become so large at the fracture that they suddenly tear the metal in two on the natural surfaces of cleavage of the crystal grains.

The center portion of this fractured surface does not differ from the crystalline surface at the bottom of a cup in an ordinary static tension fracture, except that the crystalline surfaces are somewhat larger. This is to be explained by the fact that in an ordinarily tensile test the material at the fracture has elongated something like 100 per cent, so that the crystal grains have become of smaller cross-section and will naturally show smaller facets on fracture, whereas, in a fracture of the endurance specimen, the material has had no chance to elongate and the crystalline grains have their normal size, which will be shown in fracture. It is not the crystalline portion of the broken specimen which has failed primarily by repeated stress, but the dull portion. In the crystalline part of the fatigue fracture and in the crystalline part of the static tension fracture the failure seems to be of the same nature, namely, a failure in cohesion.

In considering the phenomena of fatigue failure it may be well to call attention to the fact that there is an intermediate type of failure of ductile material in which both plastic action and the development and spread of microscopic flaws are present. Such failures sometimes occur in staybolts, boiler sheets between rivet holes, and other parts occasionally subjected to very severe local distortion.

LOCALIZED STRESSES UNDER STATIC LOADING AND UNDER IMPACT LOADING.

When a machine member or structural part is loaded gradually a state of strain and accompanying stress is set up throughout it. In a general way the distribution of stress is similar to that given by the theory of elastic action which serves as a basis of our formulæ for computing stress and strain. There are, however, many deviations from this distribution due to non-homogeneity of the material and to irregularities in outline such as projecting corners, scratches and tool marks. When load is applied the general behavior of the piece as indicated by careful measurements of stretch, compression, twist, or flexure conforms to that required by the common theory of elastic action, but there are doubtless many localized strains which cannot be detected, even by the use of delicate micrometer measurements. It is to be recalled that in measuring strains it is necessary to use a gage line of considerable length, with the result that the observed strain is an average value along a relatively long line. The localized stresses, corresponding to these undetected localized strains, are not of any great importance under static load. When the load is increased to such an extent that a considerable portion of the piece is stressed beyond the elastic limit, the distortion of the piece increases abnormally and the piece may be considered to have reached its yield point. After this limit is passed the distribution of stress is much modified, and for parts made of ductile material the abnormal distortion at the yield point usually gives warning of structural damage before complete failure occurs.

Under impact loading, which is merely loading applied in a very short space of time, the action is somewhat similar to that under static loading, except that ductile material may offer a higher resistance to very rapid fracture than it does to fracture occurring gradually through a period of several minutes. Impact fracture, moreover, may emphasize somewhat the localized stresses set up at places where the structure of the material is non-homogeneous, or at places where there are sharp notches or deep scratches in the surface of the piece. Under slowly applied load there is opportunity for considerable adjustment and equalization of stress after the yield point is passed; under impact load there is probably less equalization on account of the rapidity of the action, and hence the localized stresses are higher and more effective in causing failure. This explanation of the action under impact is given here because repeated stresses also emphasize the effect of high localized stress, though for an entirely different reason.

TESTS AND CRITERIA FOR FATIGUE STRENGTH.

It was formerly the common opinion that the determination of the elastic limit of a material by means of a static test in a testing machine gave a reliable test for the fatigue-resisting qualities of the material, and that the material could withstand an infinite number of repetitions of stress lower than this elastic limit. Tests at various laboratories, however, have quite thoroughly disproved this idea, and have thrown grave doubts on the reliability of the elastic limit as an index of fatigue strength. The term "elastic limit" has always been rather loosely used, and covers several quite different stresses. The value determined for the elastic limit for any material depends on the sensitiveness of instruments used and the accuracy of plotting results, and the elastic limit as determined by such a test in a testing machine is determined by the average behavior of the material over a considerable length, while the process of fatigue failure may be going on over a section so small that it does not appreciably affect the readings of the measuring instruments used. In several laboratories comparative repeated-stress tests of different materials have shown higher fatigue resistance for the material with the lower elastic limit.

Bauschinger in his classic experiments showed that the elastic limits in tension and compression as determined by ordinary testing-machine tests were variable limits, their value depending on the treatment of the material during fabrication. He called such limits "primitive" elastic limits, and showed that when a specimen is subjected to gradually increasing range of alternating stress there are soon set up two elastic limits in the bar—one in tension and one in compression. He called these limits, which may have values widely different from the "primitive" elastic limit, the "natural" elastic limits, and the range between them the "elastic range." He also showed that a test specimen will stand several million repetitions of this elastic range of stress without failure, and proposed the "natural" elastic limits as indices of the

fatigue-resisting strength of the material. J. H. Smith has developed a somewhat simplified process of determining the elastic range. This elastic range seems a more reliable index of fatigue strength than the ordinary "primitive" elastic limit, but the reliability of indices of fatigue strength based on determinations of any elastic limit by testing-machine tests is open to question on account of the possibility that localized fatigue failure may be in progress without affecting the readings of the instruments used in static tests.

Wöhler used as an index of fatigue strength the "endurance limit" of material as determined from a series of fatigue tests with different intensities of stress. He used the method of plotting values of stress (S) against numbers of repetitions required for fracture (N) and determining by eye where this S-N curve became "practically horizontal." Other investigators have plotted values of S against values of $1/N$ or of $(1/N)^n$ and by extending the diagram till it intersected the axis of ordinates have determined an assumed endurance limit for an infinite number of repetitions of stress. Both of these methods involve enormous extrapolation of test data. Moreover, widely different endurance limits can be determined from the same test data by different methods of plotting values. The tendency to irregularity of test results under low stresses makes the decision whether the S-N curve is horizontal or slightly sloping downward one of very considerable uncertainty.

It has been proposed by various experimenters to compare the fatigue-resisting qualities of different metals by short-time tests with stresses well beyond the yield point of the material. Such tests are quickly and easily made. Under such stresses, however, the action of the material is partly a plastic flow. Such tests give good promise of determining fatigue strength and toughness under occasional overload for parts such as staybolts, which in their ordinary service are subjected to rather severe distortion, but it is not at all certain that such tests give a reliable index of resistance of machine parts under ordinary working stresses.

It has been proposed by various laboratories to compare the fatigue strengths of various materials by comparing their life under repetitions or reversals of some standard stress, usually less than the elastic limit of the material as determined by a static test. A somewhat similar standard proposed is to determine the stress which will cause failure under a given number of reversals. Standard stresses proposed for steel are 38,000 lb. per sq. in. (reversal) and 25,000 lb. per sq. in. (reversal). One million reversals has been proposed as a standard "life." These two types of test approach working conditions more closely than do the short-time, high-stress tests described above. However, they determine only one point on a S-N diagram for a material and do not indicate how fatigue endurance changes with change of stress.

A comparative study of fatigue strengths of various materials can be made from a S-N diagram plotted on logarithmic paper. Up to about 1,000,000 repetitions of stress logarithmic S-N diagrams fall quite closely along straight lines, and from the ordinates and slopes of these lines the behavior of materials under various intensities of stress can be studied. Tests may conveniently be made with stresses at about the yield point of the material, at stresses about 20 per cent lower, and at one or two intermediate stresses.

Various other possible tests have been proposed for determining the fatigue-resisting strength of a material, but no test has been proved to be of sufficient reliability to be accepted as a standard. A number of tests, however, seem worthy of experimental study.

The rate of dying out of vibrations in a "tuning fork" specimen of the material has been suggested as a possible index of fatigue strength. It is assumed that the gradual dying out of vibration is due largely to loss of energy spent in inelastic action in the material, and that such inelastic action is a measure of the fatigue weakness of the material. Test data are lacking to determine the value of this test, but it seems worthy of study.

Tests of magnetic permeability have also been proposed to locate internal flaws in the material and thus indicate its relative fatigue strength. The entire subject of the correlation of the magnetic and the mechanical properties of iron and steel is a promising field of investigation.

The rise of temperature under repeated stress has likewise been proposed as a measure of fatigue resistance. Theoretically, if a specimen is subjected to reversed elastic stress no change in temperature should take place, and it has been proposed to determine the endurance limit for metals at that stress which causes the first noticeable rise in temperature after some thousand or more reversals. A practical difficulty in using this test is to secure proper heat insulation for the specimen. This test seems worthy of study, however, especially if employed in an inertia type of testing machine (see Figs. 3 and 4).

The detection of the appearance and growth of "slip lines" in a specimen subjected to repeated stress gives some promise of furnishing a reliable test for fatigue strength. Slip lines appear long before fracture occurs, and if their appearance or the rate of their spread can be shown to be an index of fatigue strength it seems possible that a feasible laboratory test may be devised. The search for slip lines over any considerable area would, however, be very tedious.

Impact tests, usually on notched bars in bending, have been proposed as an index of fatigue strength. The actions under impact failure and under repeated stress are very different, the first giving a sudden break of the entire cross-section of the specimen, and the second a gradually developing fracture. Both failures, however, seem to be affected by localized flaws or irregularities in outline, and though no definite correlation between fatigue strength and strength to resist impact has been established, yet such tests are worthy of study. Repeated-impact tests have also been proposed to determine fatigue strength, but whether such tests have any advantage over short-time tests under non-impact loads is not known.

In all tests to determine fatigue strength it is of the highest importance to secure uniformity of surface finish between the different specimens to be compared. Probably this can best be done by polishing the surface of the specimens where failure is expected.

There is today no short-time test accepted as a standard test for fatigue strength; but the development of such a test, and the establishment of its reliability, would unquestionably be of very great service to testing engineers.

LOCALIZED STRESS AND ITS INFLUENCE IN PRODUCING FATIGUE.

The ordinary formulæ and methods of analysis used in computing the fiber stress in a machine part or structural member are based on the assumption that the material is homogeneous throughout, and that the cross-section of the member is either constant or that it changes its dimensions so regularly and gradually that there is no appreciable localized fiber stress at sections of rapid change. For structures and machines of ductile material subjected to not more than a few hundred loadings, such assumptions are reliable, because localized stresses do not appreciably affect the general deformation of a member, nor do they under ordinary working conditions cause trouble before the member has been subjected to some thousand or more repetitions of load. For nearly all parts, however, high localized stresses are present. Internal flaws may cause such localized stresses. This is shown by mathematical analysis of stress in plates with holes in them and by direct experiment on such plates. External irregularities of outline may cause localized stress. Under bending or twisting a member with a sharp reëntrant angle in its outline theoretically develops an infinite stress at the root of the angle, and actually both mathematical analysis and direct experiment show that very high localized stress may be caused by sharp grooves or

scratches on the surface of a machine part or structural member.

It has been stated above that for parts subjected to a few loadings localized stresses are not of great significance. The case is quite different, however, for parts subjected to thousands of loadings. High localized stress may cause a crack to start, either directly or by "cold-working" the material where the localized stress exists until the material becomes brittle. This crack forms an extension of the discontinuity of the material which caused it, and under repeated stress tends to spread still more rapidly. This tendency is illustrated by the action of a piece of plate glass in which a crack has started. In most cases under any repetition of load the crack spreads, and will cause final fracture of the glass. A fatigue failure under repeated stress is a progressive failure. This spreading of cracks to cause failure explains why under fatigue even ductile materials snap short off. Failure does not involve plastic flow of considerable masses of metal, but only of microscopic masses near the crack, and final fracture comes suddenly just as if the member were cut half off by means of a saw cut and then bent. The importance of avoiding localized high stress in members subjected to repeated stress can hardly be overemphasized. Homogeneity of internal structure, smoothness of external surface, and avoidance of sudden changes of cross-section may be more important in the construction of machine parts subjected to repeated stress than is high static strength of material.

Shoulders of crankshafts and of axles, keyways in shafts, screw threads, and rivet holes are examples of locations where high localized stress is liable to occur.

RELATION BETWEEN MICROSCOPIC STRUCTURE AND FATIGUE.

A very large field of investigation and one in which very little systematic work has been done is the study by means of the microscope of fatigue failures in various characteristic structures of metals, especially steels. The following paragraphs are given as a summary of the theory held by present-day metallographists of the relation of microstructure of metal to its fatigue strength. Many of the details of this theory, however, lack adequate experimental verification.

Annealed steel consisting of ferrite (pure iron) and cementite (iron carbide, Fe_3C) seems to increase in resistance to fatigue with the increase in carbon content, especially when the cementite is present in the form of plates as in lamellar pearlite and as long as the cementite does not surround the grains of pearlite. When the cementite is spheroidized, the elastic limit is greatly decreased and probably the resistance to fatigue is also decreased. As a structural material, therefore, a steel with considerable carbon in the form of spherical globules of iron carbide would have practically no advantages over wrought iron. When, however, the iron carbide is in plates it seems to have a marked effect in raising the elastic limit, and probably increases the resistance to fatigue. We would also expect that complete and large networks of ferrite would lower fatigue resistance.

The same arguments regarding grain size of single constituent metals hold to a certain extent for two component alloys. For example, such experimental evidence as is available indicates that the sorbitic structure in steel is the one which resists fatigue best. This structure is supposed to represent an extreme refinement of grain in which the particles of iron carbide are very small, and hence the particles of ferrite must also be very small. It is true that some of the iron carbide may be in solution in the iron, but it is more probable that the mechanical properties observed can be accounted for by an extreme reduction in the size and by the dispersion of ferrite and cementite particles. When these globules are made larger by heating to a higher temperature than that at which the sorbite was formed, granular pearlite results with reduced fatigue resistance.

When a high-carbon steel is quenched from above the critical range to form martensite, the metal becomes extremely brittle. The normal path of static rupture in brittle martensite is at the old austenite (solid solution of Fe_3C in gamma iron) grain boundaries. The path of rupture in fatigue has, so far as is known, not been ascertained. From certain tests on the resistance to fatigue of chrome-vanadium steel after various heat treatments, Dr. C. M. Olmstead of the C. M. O. Physical Laboratories, Buffalo, found that the steel in the martensite state, that is, as quenched, had a very much lower resistance to fatigue than after reheating to about 1,100 deg. fahr. The maximum resistance to fatigue occurred by quenching and reheating to 1,000-1,200 deg. fahr. (538-648 deg. cent.), and there was very little difference between the specimens tempered at 1,000 deg. and at 1,200 deg. There was a marked difference, however, between these and the samples tempered at lower tempratures or those not tempered at all. This is the heat treatment that is commonly given to automobile parts which must withstand fatigue stresses, and which may be subjected to shock. The tempering of springs is done at a little lower temperature, but it is not certain that the spring structure is the one having the highest resistance to continued repetition of stresses.

It seems from the above that martensite is not a suitable material to withstand fatigue stresses, and that some intermediate structure between martensite and the annealed or normalized structure will have the maximum resistance to fatigue. This structure is called the sorbitic structure and corresponds to that used in automobile springs and other parts of automobiles which must resist fatigue and shock stresses.

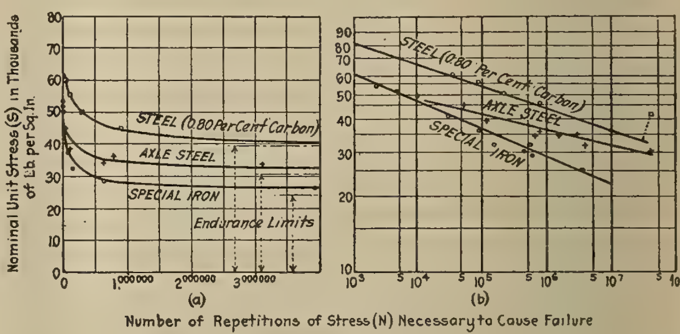


FIG. 6. STRESS-STRAIN DIAGRAMS

FORMULÆ FOR DESIGNING PARTS SUBJECTED TO REPEATED STRESS.

All formulæ which have been proposed for designing parts subjected to repeated stress depend upon extrapolation from test results and should therefore be regarded as tentative. Their use is justified only on the ground of necessity. Parts must be designed to resist repeated stress, and even formulæ derived from a confessedly inadequate experimental basis seem better than mere guesswork. Two types of formula have been used.

In many discussions of data of repeated-stress tests, it is assumed that there exists some definite "endurance limit," that is, some stress, greater than zero, which can be repeated an infinite number of times without causing failure of the material. If such a limit exists it is certainly lower than the elastic limit of the material as determined by static tests, for actual failures of materials have occurred under repeated nominal stresses as low as one-quarter of the elastic limit as determined by a static test. Examination of test data indicates that the endurance limit is an assumption rather than a proved fact. It is usually determined by plotting a diagram with stresses as ordinates and number of repetitions producing failure as abscissæ and estimating the stress for which the diagram seems to become horizontal. Various other methods have been proposed, but all involve this assumption.

In 1910 a paper presented before the American Society for Testing Materials pointed out that an examination of the results of numerous series of repeated-stress tests indicates that

for nearly all the range covered the law of resistance to repeated stress may be expressed by the equation:

$$S = KN - m \ldots\ldots\ldots\ldots\ldots [1]$$

in which S is the maximum unit stress developed in the test piece, N the number of repetitions of stress necessary to cause failure, and K and m are constants depending on the material and somewhat on the manner of making the test. This is known as the "exponential equation for repeated stress."

Another form of expression for the above equation, and frequently more convenient, is:

$$\log S = \log K - m \log N \ldots\ldots\ldots\ldots [2]$$

If the logarithms of S and N are plotted, or if the values of S and N are plotted on logarithmic cross-section paper, Equation [2] is represented by a straight line. In Fig. 6*a* ordinary coördinates are used, but in Fig. 6*b* the coördinates are logarithmic. For large values of N the exponential equation gives in many cases values of S smaller than the observed values; in other words, the exponential formula seems to err on the side of safety.

It will be noted that the use of the exponential formula involves the assumption that any stress if repeated often enough will eventually produce failure of the material. Thus while both the endurance limit and the exponential formula are based on extrapolation from known data, the exponential formula seems to be an assumption on the safe side. The working stresses as developed by the two methods do not differ greatly except for members subject to more than ten million repetitions of stress. Above that number the exponential formula requires lower working stress, but even then the stresses given by the exponential formula are not impracticably low.

While nothing but tentative formulæ can be proposed now, some features which a satisfactory formula for fatigue strength should include may be noted. It is probable that such a formula for any material will not depend on ordinary static qualities of the material such as elastic limit or tensile strength. It may depend on some form of elastic limit determined after the material has been put in a "cylic" or "normalized" state by a number of reversals of stress. Such a formula will quite probably contain factors dependent on the surface finish of the part and upon the uniformity and regularity of its crystalline structure. It will contain a factor dependent on the range of stress during a cycle. Such a formula may contain a factor dependent on the probable number of repetitions of stress which the part may be expected to withstand during a normal period of service, or the result may be an "endurance limit"—a stress which the part is capable of withstanding so many times that even for modern high-speed machinery the number of repetitions may be regarded as infinite.

SPECIAL SUBJECTS NEEDING INVESTIGATION.

Long-Time, Low-Stress Fatigue Tests of Metals. It is not known today whether machine or structural parts can withstand an infinite number of repetitions of any stress, however small. It is not known what share of blame for the occasional failures of test speciments or of actual parts in service under low nominal stress should be attributed to weaknesses in the metal structure to localized damage to the surface with resulting increase of localized stress over nominal stress, or to "harmonics" of high stress due to interference of waves of stress traveling through the part. There should be undertaken an extensive series of long-time, low-stress tests on typical irons, steels, and other metals. It is doubtful whether any series of tests can settle the question of the existence of an endurance limit, but a considerable amount of test data for endurances up to, say, 100,000,000 repetitions will give a better basis for working formulæ than is now available.

Study and Comparison of Different Testing Machines for Fatigue Tests. Different testing machines for determining fatigue-resisting qualities do not always give consistent results. A series of tests of samples of several typical metals run on various testing machines should give some indications of the reliability of various types of testing machines and perhaps enable correlation to be made between tests on different machines. For all series of fatigue tests careful chemical and microscopic tests of the material should be made to insure uniformity both of chemical content and of structure. Careful tension, compression, and torsion tests should also be made so as to insure uniformity of static strength qualities, and to give data for the study of correlation between static strength and fatigue strength. Short-time, high-strain, repeated-stress tests and impact tests should likewise be made to give data for the study of correlation between toughness, impact resistance and fatigue strength. All test specimens should be prepared with great care and surface conditions be kept as uniform as possible. It appears that this uniformity could be best secured by giving the surface a high polish.

Relative Importance of Surface Condition and Structural Characteristics as Shown by the Microscope. It seems practically certain that fatigue fractures may be started either at a surface imperfection or at an internal flaw, such as a "snowflake" or a "transverse fissure." The importance of these two types of defect might well be the object of experimental study. In connection with such a study there should be a study of methods of detecting internal flaws, such as deep etching, and a study of methods of indicating the degree of perfection of surface finish.

Effect of Grain Size of Metal on Fatigue Strength. On this subject Rosenhain says:

"The question then arises whether the increased size of crystals produced in a simple metal by prolonged heating is injurious or otherwise, so far as the useful properties, and more especially the mechanical properties, of the metal are concerned. There can be little doubt that within reasonable limits the mechanical properties of a simple metal are better the smaller the constituent crystals of which it is built up. Under the tensile test, coarseness of structure usually results only in a slightly lowered yield point, while the ultimate stress and the elongation are little impaired, although the reduction of area at fracture is sometimes markedly less. On the other hand, under both shock and fatigue tests, a coarse structure, even in a simple metal, gives unsatisfactory results."

Tests and service records quoted by Jeffries and by Ruder tend to confirm this opinion in the case of copper. Fine-grained copper is very much more resistant to repeated stresses than coarse-grained copper. Also if the elastic limit of fine-grained metals is determined by delicate instruments, it is generally found to be greater than that of the same metals in the coarse-grained state. Systematic tests should give us a firmer basis for conclusions in this important phase of fatigue phenomena.

There have been found no records of microscopic analyses dealing with the path of rupture under repeated stress in steels having various structures from martensite to the normalized state. A study of the path of rupture and the manner of rupture in these samples would be most interesting.

Development of Special Tests for Fatigue Strength. At present there is no short-time test for fatigue strength which has been proved to give reliable results. Some tests which give promise of usefulness are:

1. The Rise-of-Temperature Test used by Mr. Stromeyer. In this test the highest reversed stress which a specimen can stand without appreciable rise of temperature is taken as an index of fatigue strength.

2. The Development of "Mechanical Hysteresis." If a fatigue failure is in progress in metal subjected to repeated stress, very small amounts of energy are lost during every cycle of stress. The energy lost during each cycle may be too small to measure, but after some hundreds or thousands of cycles the cumulative effect of the losses may become appreciable. This loss may appear as a "loop" in the stress-strain diagram for a complete cycle of stress, and this indication may be detected at a comparatively early stage of the

fatigue failure. Dr. Stanton of the British National Physical Laboratory has made some experimental study of this development of "mechanical hysteresis," as this loss of energy is called. It is possible that mechanical hysteresis may be studied by the dying out of vibrations set up in a test piece, as has been proposed by Boudouard.

3. Magnetic Testing of Steel for Fatigue Strength. The structural damage done while a progressive fatigue failure is occurring may, possibly, be detected and measured by the change in magnetic permeability of the steel. Burrows, Dudley, and Sanford have done some experimental work on this subject, and magnetic analysis seems worthy of study as an index of fatigue strength.

4. Impact Tests and Repeated-Impact Tests. Although the action of metal under impact is very different from its action under repeated stress, yet both impact and repeated stress seem to emphasize local irregularities and imperfections of surface or structure. It may be that a repeated-impact test may be devised which will give a reliable measure of fatigue strength, and which will do so in a comparatively short time. Such tests seem worthy of study, though their value as tests of fatigue strength cannot be said to be established.

It is believed that the foregoing paragraphs outline fundamental investigations, many of which should be undertaken at an early date. Experimental study of typical metals under long-time, low-stress tests; study by means of the microscope of the phenomena of fatigue failure in metals of various crystal structures; and study of reliable test methods of determining fatigue strength constitute, in the opinion of the committee, the fundamental line of research in fatigue phenomena. Once such fundamental tests have made fair headway, especially the determination of a reliable test for fatigue strength a large number of problems call for study.

A TRIGONOMETRIC COMPUTER.

By F. E. WRIGHT, Geophysical Laboratory, Carnegie Institution of Washington.

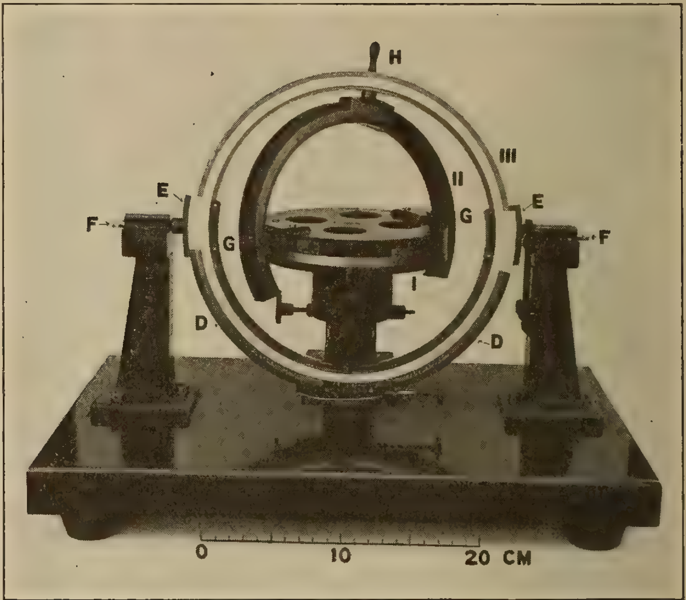
THE solution of spherical triangles by the logarithmic computation of trigonometric formulas is at best a time-consuming process, especially if there be many such triangles to solve. In case high precision is required no other method is available; but if only approximate results are desired, graphical methods may be used, such as an exact projection net; of these the stereographic net published by G. W. Littlehales[1] is the most accurate and furnishes results correct to about 2′ of arc under favorable conditions. If the results are to be correct within one-half minute of arc graphical methods are not adequate and recourse must be had either to computation or to some mechanical device of high precision.

In crystallographic work the degree of precision is of the order of magnitude of ½′. In the measurement of the changes in crystal angles with temperature the position of each crystal face is determined on the two-circle goniometer by means of two angles (polar distance and azimuth). Having given the position-angles of any two faces, the angle between them can be found by the solution of a spherical triangle.

In 1913 the writer had occasion to solve many triangles of this type, and to save time had a mechanical computer constructed in the instrument shop of the Geophysical Laboratory. This instrument has proved to be satisfactory in practice for the solution of oblique spherical triangles in which three of the angles are given and the value of any one of the three remaining angles is sought with a precision of about half a minute. The computer was designed for, and functions best in, the solution of the problem; given two sides and the included angle of a spherical triangle; find the third side.

Description of Instrument.—A photograph of the instrument is reproduced in the accompanying engraving. It consists essentially of three concentric graduated circles which can be inclined at different angles one to the other. The inner circle I is horizontal and can be rotated about a vertical axis. The outer circle III fits in the semicircular groove *D* and is free to turn in this bearing, the angle of turning being read off on the vernier at *E*, *E*; the circle in its bearing can also be rotated about the horizontal axis *F*, *F*. The intermediate circle II is not a complete circle and is attached to the circle I by the horizontal axis *G*, *G*, and to the circle III by the axis *H*. The angles of rotation and revolution of these circles can be read off on appropriate verniers. The circles are equipped with clamp screws and slow-motion devices for the accurate setting of angles.

[1]Altitude, azimuth, and geographical position. J. B. Lippincott Company, Philadelphia, 1906.



INSTRUMENT FOR COMPUTING SPHERICAL TRIANGLES

The following steps are taken to solve the problem: given two sides *a*, *b*, and the included angle *C* of a spherical triangle; desired the third side *c*.

Set the three circles at right angles to each other—all verniers reading 90°. Turn circle III about the horizontal axis to the position where it includes the angle *C* with the horizontal circle I (angle read off on the vernier of circle II). Turn circle II in its bearing until axis *H* includes an angle *a* with the axis *F*, *F*; turn horizontal circle I about its axis until axis *G*, *G* includes the angle *b* with the axis *H*. The angle *H*-*G* is then the desired angle *c*. The entire operation requires about one minute and is simple and readily checked.

The instrument is necessarily one of high precision, and first class workmanship is required to produce a satisfactory computer. In its construction care was taken to include adequate adjustment facilities such that the instrument can be readily adjusted in case of wear. The instrument is mounted on a heavy cast-iron base.

ELECTRIC POWER FROM TIDAL CURRENTS.

TESTS carried out in the River Mersey with the Clarkson tidal turbine have shown that electrical power can be obtained from tidal currents at an estimated cost of less than a penny per unit.

The turbine consists of rows of buckets or paddles attached to endless chains, these running over sprockets mounted on a floating framework. There is thus a lower row of buckets immersed in the water, and an upper row out of the water traveling in the opposite direction. It is the pressure of the current acting on the buckets which causes the sprocket shafts to rotate, and so enables a dynamo or other apparatus to be driven. By the use of reversible mechanism, the turbine may be adapted for generating energy equally well on an ebbing or a flowing tide.—Abstracted by *The Technical Review* from *Practical Engineer*, Nov. 27, 1919.

Photo-Micrography Without a Microscope*

Simple Apparatus for Low Power Magnification

By G. Ardaseer

WITH low-power photo-micrography—say, up to x 12—a microscope is not generally necessary, and any photographer who possesses a short-focus lens of about 3-inch focal length, and a camera with long extension, can set about doing quite successful work. The writer used for such purposes a Voigtländer Collinear of 70 mm. focal length—say, 2 4/5 ins.—and with a triple extension half-plate camera of 23 ins. when fully racked out he gets a magnification of x 7 without any additional extension device. The extensions are readily calculated from the formula $(M + 1)\ f =$ distance between ground-glass screen and, for convenience, lens diaphragm, where M is the number of desired magnification and f the focal length of the lens.

Consequently for	x4	the extension	should be	14″
"	" x5	"	"	16 4/5″
"	" x6	"	"	19 3/5″
"	" x7	"	"	22 2/5″

Of course, with a lens of shorter focal length, such as an Aldis 2 in., the magnifications will be greater with the same extension.

To rig up the apparatus it is best to have a base-board, along the centre of one side of which a line is ruled lengthways. This simplifies centering the light and the object. The latter is held in some kind of holder, which will allow it to be adjusted to the axial line of the lens, and the illuminant is also adjusted to the same line. The diagram (Fig. 1) will indicate what is meant. AB is the baseboard, CD the camera, F, a tubular extension to fit camera and take lens L, H the slide holder, shown in detail in Fig. 2, and Z the illuminant. The tubular extension used by the writer consists of a piece of a stout cardboard tube—originally that in which bromide paper was packed—about 6 ins. in length and 2½ ins. diameter, and cut off accurately square; one end glued into a wooden camera front-piece and the other end fitted with a wooden disk with central hole to take the lens flange. It is important that the lens axis should be truly horizontal, and care must be taken to keep the disk end square with the tube. The object holder must have a hole about 1½ in. cut, but with its center exactly level with the height of the lens center above the base board. The holder can be fastened to the base board, or its base may be weighted to give rigidity. The light—the writer uses an inverted incandescent mantle—slides upon a rod on a heavy square base. If runners are attached to the base board, between which the holder and light-standard can slide, matters are made easier in adjusting the illumination. The camera is clamped to the base-board, and the whole arrangement is such that the center of the focussing screen, the center of the lens, the hole in the holder, and the light are in one straight line. There is a small ledge, LL (Fig. 2), on the holder on which to rest the slide, and two curved pieces of watch spring, SS, are screwed upon it to maintain the slide in a vertical position.

A penciled cross is marked on the ground-glass focussing screen at the intersection of its diagonals. The light is centered by focussing it on to the screen and moving it up or down or sideways until the image of the mantle is central with the cross. A piece of cardboard 3 ins. by 1 in., with a small hole in the center, is placed in the holder, with this hole central to that in the holder, and the same focussing and adjustment of the holder is to be observed. The object—say, a section of wood—is placed in position, focussed first by racking out the front of the camera and a final sharp focussing—seen best through a focussing glass, set to give a sharp image of the penciled cross on the ground glass—is effected by racking the back of the camera in or out until every detail is sharp. The light is cut off, preferably by interposing a piece of black card against the lens and between it and the object. The dark slide is inserted, the shutter withdrawn, sufficient time allowed to admit of all vibration ceasing, and then the card withdrawn and exposure made. The card is then replaced and the shutter closed. In many cases where the object is colored a color filter is almost a necessity, and a small holder for it, somewhat similar to the object holder, can easily be improvised. The filter should be placed close to the object (F in Fig. 1) and between it and the light. For mounted insects—generally of a yellowish color—a K3 filter is very useful. The Wratten series of M filters, although intended for M panchromatic plates, are almost essential for successful results with other plates.

For opaque objects the light or lights are placed at the side of the camera, but behind the lens, so that no direct light falls into the lens, and sometimes a couple of lengths of magnesium ribbon burned one on each side will give excellent results. In fact, the procedure in this case is similar to that of copying. In a short article minute details cannot be entered upon, but there is one point, exposure, which is most important. Insufficient exposure is fatal to success, and the judicious waste of a few plates, in the sense of two or three strip exposures on one plate, will do much to give an idea of

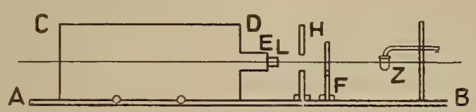


FIG. 1.

FIG. 2

the correct time to expose. This, too, is governed to a large extent by the color of the object, yellow, red, or brown objects requiring a very long time as compared with white, grey, or blue.

When focussing with the focussing glass it is very convenient to cement one or more microscope cover glasses with Canada balsam to the ground-glass side of the screen, and to focus the aerial image so produced. The writer, however, generally uses a focussing screen of his own make, as described by him in the *Journal* of June 27 last. He feels sure that any photographer who tries this method of low-power work will not stop there, but will desire to have a microscope as well, and wed it to the camera.

*Reprinted from *The British Journal of Photography*.

IMPROVED WEHNELT INTERRUPTER.

A NEW form of Wehnelt interrupter was exhibited by Mr. Newman at the meeting of the Physical Society on Dec. 5 last. Owing to the rapid disintegration of the platinum wire and because the current required for the working of the cell is large, the Wehnelt interrupter is not generally used. In the modified form, a plate of aluminum, having an area of 50 sq. cm. is substituted for the lead plate, the other electrode being platinum wire sealed in a glass tube. The electrodes are immersed in a saturated solution of ammonium phosphate made alkaline with ammonia. The interrupter works equally well with direct or alternating currents. The minimum potential difference required is 18 volts, but the frequency of the interruptions increases with the applied voltage.—Abstracted by *The Technical Review* from *The Chemical News*, Dec. 5, 1919.

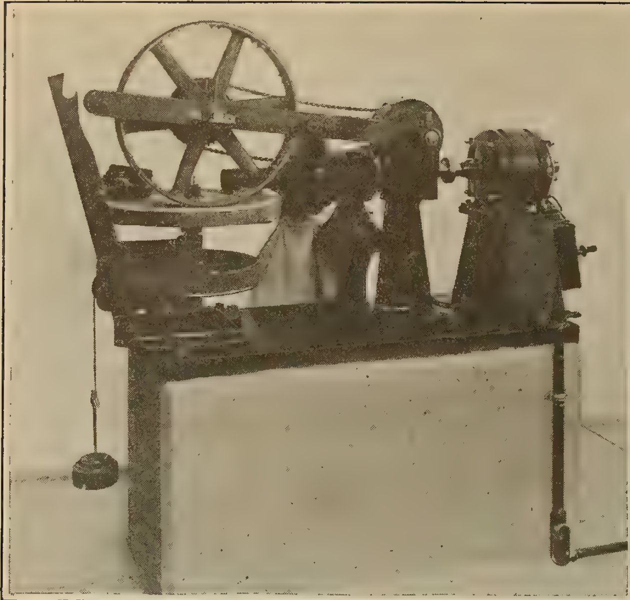


FIG. 1. WEARING TEST MACHINE AS USED AT PRESENT

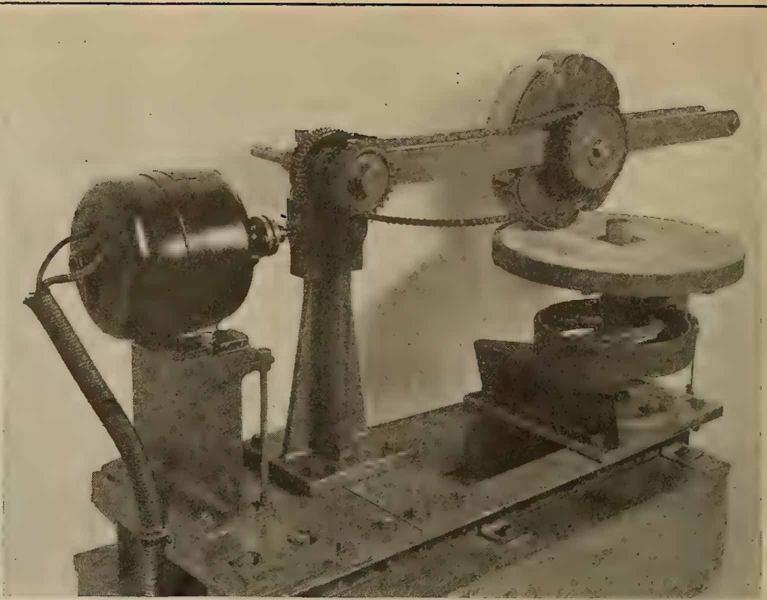


FIG. 2. WEARING TEST MACHINE AS FIRST USED

Measuring the Relative Wear of Sole Leathers*

Results Obtained with Leather from Different Parts of the Hide

By R. W. Hart and R. C. Bowker

THE quality of sole leather is affected by many factors, such as the breed of the animal, its mode of life, the time of killing, the method of preserving the hide, and the kind of tannage. A very important factor which influences the durability of any particular sole is the part of the hide from which it is cut. It is a difficult problem to measure the wear of sole leather and generally it is accomplished by actual service tests on individuals. Such a method takes considerable time, and the value of the results obtained is often uncertain on account of the many uncontrollable variables occurring in the types of service and among the individuals wearing the soles. The development of a simple method for quickly determining the durability of sole leather seemed desirable, and this paper discusses a laboratory apparatus designed for this purpose and also presents the results of tests made to date to determine the relative wear of leather from different parts of a hide.

WEARING-TEST MACHINE.

A machine has been developed at the Bureau for testing the durability of sole leather with the idea of subjecting the leather to shearing action during the wear similar to that occurring in service on shoes and at the same time accelerating the actual wearing away of the material so that an indication of the durability of the specimen might be obtained in about 24 hours. The machine as first designed (Fig. 2) embodied a cam of clover-leaf shape, to which the samples were attached, and which rested on a horizontal disk having an abrasive surface of cement. The difficulties with this design were that the samples were submitted to a bumping action which caused the wear of each sample to be so localized that it was often worn through on one end before the other end showed appreciable wear, that no means was provided for removing the material worn away, and that the abrasive material soon wore smooth which caused a longer time to be necessary for a test. The machine (Fig. 1) as later developed and as now used is described as follows:

A wheel of 15-inch diameter carries on its face 12 test pieces. The wheel revolves at the rate of 30 revolutions per minute about a horizontal axis with its bearings in two parallel metal bars which are pivoted at one end, the other end being free. The wheel carrying the weight of the bars (and any additional weight that may be suspended from their free ends), rests on a horizontal disk of 16-inch diameter, the point of contact being 5½ inches from the axis of the disk. This disk has a surface of carborundum, and rotates about a vertical axis on which is a brake wheel provided with a brake strap, by means of which any desired resistance to rotation may be secured by the application of dead-weight. The wheel is driven by a chain and in turn drives the horizontal disk with which the test pieces are in contact. The apparatus is designed with the view of subjecting the test piece to (1) a driving (shearing) action under pressure, and (2) a slight abrasive action resulting from the circular path of contact between the wheel and disk. The conditions of pressure and shear may be adjusted as desired. A circular brush is shown resting on the carborundum disk. This brush in connection with a small exhauster tends to keep the surface of the wearing disk clean.

A test usually consists of 40,000 revolutions of the wheel which corresponds with 40,000 steps, or approximately 40 miles of walking.

The substitution of a wheel for the cam eliminated the bumping action but retained the shearing action and resulted in a more even and smoother operation. The use of a wheel allowed more specimens to be tested at one time, the entire surfaces of which were subjected to the wearing action. By using carborundum for an abrasive, a material was obtained which did not become dull or smooth quickly and which could be resurfaced with an emery-wheel dresser.

A small suction fan and circular brush were added to the equipment in order to remove the dust caused by abrasion. These improvements permitted the wearing conditions to be more uniformly maintained.

METHODS.

Sole leather is generally sold in the form of bends. A bend is a half of a hide with the shoulder and belly portions trimmed off, the remaining portion being suitable for soles.

*Technologic Paper No. 147 of the Bureau of Standards.

In the tests conducted samples of leather from different locations on a bend were used to determine their relative durability or resistance to wear. When a whole bend was tested the general scheme was to divide it into blocks, as illustrated in Fig. 3. Each block was stamped with a code number, which fixed its location on the bend. When using the cloverleaf-shaped cam for holding the samples, test pieces approximately 24 by 5 cm. were required and they were attached to the cam by a clinching device. Test pieces for use with the wheel were about half as long and were attached by means of four countersunk screws. In either case the samples were

FIG. 3. A BEND MARKED OFF FOR MACHINE WEARING TEST

first weighed and then placed on the machine. After the test was completed the samples were again weighed and the loss in weight determined. The relative durability was obtained by determining the loss in volume from the loss in weight and the specific gravity. The sample showing the greatest loss in volume was considered as the least durable.

A small sample adjacent to the test specimen was used in determining the specific gravity. Since only the grain portion was worn away during the test, it was thought desirable to use the specific gravity value for the grain portion only. Accordingly the flesh portion of the sample was removed and the grain portion was then coated with cellulose nitrate to render the sample water-proof. The determinations were then made using a direct-reading gravitometer (Fig. 4).

CONCLUSIONS.

The results of these tests show that the machine indicates a decided difference in the wearing quality of leather taken from different parts of the hide, the portion near the back and over the kidneys having the best wearing quality and those portions near the belly edge, shoulder end, and extreme butt end having considerably less durability. These indications are in accord with the opinion and experience of many tanners and leather manufacturers. The results obtained on the machine in Test No. 4 also agree quite closely with those obtained in service tests.

In view of these facts it seems reasonable to believe that the machine may properly be used to indicate the relative resistance to wear of different leathers.

Owing to limitations of space the description of the series of tests with the two machines are omitted.—EDITOR.

MANUFACTURE OF BUILDING STONE OUT OF CINDER OR SLAG.

THE present scarcity of building material has led to a new form of industry in Germany. At some large gas-works, notably at Heidelberg, Fürth, and Stuttgart, and other works where cinder or slag is produced, the manufacture of artificial building stone has been undertaken.

The stone is produced in blocks of a convenient size, usually 10 by 12 by 25 centimeters. It is formed of a definite mixture of cinder and cement, with either sharp sand or limestone. Its resistance varies, according to the composition, from 20 to 50 kilograms to the square centimeter. Thus 1 cement to 8 cinder gives a resistance of 205 kilograms, while 1 cement to 6 cinder and 2 sand gives a resistance value of 51.5 kilograms. Commonly adopted proportions are: 8 parts of cinder sifted to 10 mm. size; ¾ parts cement; and ¼ limestone, which give a resistance of about 30 kilos, and sufficient for the walls of ordinary buildings.

Only such cinder is suitable for this manufacture that has lain in the waste heap for a considerable time. Chemical action takes place in waste heaps, which action must be left to work itself out. This is especially important where sulphate of lime may be formed. The presence of magnesia is objectionable on the ground of its forming magnesium salts, which, being hydroscopic, tend to keep the walls damp. If limestone is used in the place of sand, it should be of an hydraulic nature. The sand should be clean; *i. e.*, free from clayey matter. In some gas-works the manufacture is carried on entirely by hand-labor, iron forms being used to shape the blocks. One man using these molds, can make in an eight-hour shift from 400 to 500 blocks. In from three to four weeks the blocks are sufficiently set for use.—*Dr. Karl Bunte, Journal für Gasbeleuchtung*, Oct. 18, 1919. Abstracted through *The Technical Review.*

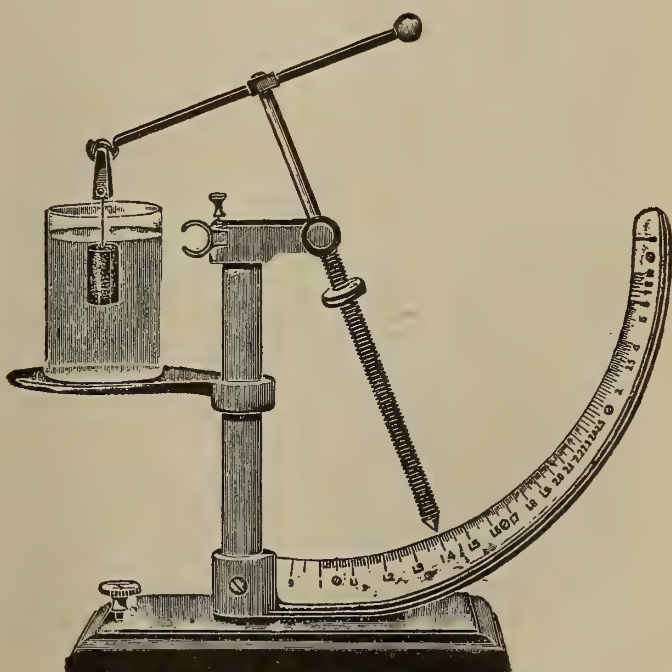


FIG. 4. DIRECT READING GRAVITOMETER

U. S. S. HENDERSON IN COMMISSION. THE PATCH IS OVER TWICE THE SIZE OF THE STABILIZER

Non-Rolling Passenger Liners*

Observations on a Large Stabilized Ship in Service

By Edward A. Sperry

NOW that it has been adequately demonstrated in the case of a number of important installations that a ship can be guaranteed against all rolling, a great forward step is possible and a new era opened up for the American passenger-carrying service. The traveling American demands the greatest possible degree of comfort, and shipping interests will not be slow to meet this demand by the latest and most up-to-date equipment cast strictly on American lines.

We will have at no distant date the Service-de-Luxe on the Atlantic and probably also on the Pacific, or, in American travel lore, the "Pullman Service of the Sea." Plans are already in progress for an extensive adoption of the new principle, so that the benefits and economies resulting from a ship guaranteed against roll will be available to the traveling public. This great forward step has been made possible by work going on here in America for the past fifteen years.

The point of large-scale demonstration has now been reached and full stabilizing moments, requisite for preventing all roll of even the largest ships, have been practically developed. The great principle thus finally established is that full stabilizing moments, can now be simply and effectively delivered to a ship that is quiescent and entirely free from motion. The motion of the ship itself having heretofore invariably been relied upon to create the quenching moments, anything like full extinction of roll has of course been impossible.

In all previous attempts to prevent rolling, the equipment has operated on the passive principle, depending on a certain amount of roll for the stabilizing moments, as stated; and the amount by which the roll has been reduced has never been satisfactory, nor have the means themselves been practicable. Another difficulty is that the phase lag is found to be insurmountable, the stabilizing effect—such as it is—arriving "the day after the fair."

The active gyro stabilizer solves the problem and works entirely independently of the motion of the ship. Delivering full counter-movements to a motionless ship, it is thus free to deal directly with the wave slopes themselves, *i. e.*, with the rolling increments of the sea as they are in the process of developing, even before incipient rolling has set in. The active stabilizer thus acts as a simple preventive of rolling, working in harmony with the slow period of the ship, yet dealing alertly with each increment as it arrives, irrespective of magnitude or direction; holding the ship most satisfactorily upon an even keel, apparently without effort; demonstrating how little is required to keep a ship from rolling, or, rather, from beginning to roll, if a basically preventive method is employed.

With the complete solution thus in hand, accomplished with a small and simple equipment, it is believed that the older passive types, with their great weight, fractional results, and uncertain operation, will become obsolete.

The equipment that brings about this important result is so simple and unique that a brief résumé of its development, the principles involved, and the performance of the non-rolling ship itself cannot fail to be of interest at this time.

The possibility of producing the non-rolling ship was known to the leading naval architects and investigators in England, notably the elder Froude, prior to 1880. A little later Sir Phillip Watts, one of the great masters of this noble art, became convinced from Froude's work that, inasmuch as it takes so little to hold a ship on an even keel and to prevent it from rolling, this very desirable result should be accomplished. As Chief of Construction of the British Admiralty, he, with a corps of engineers, at once started in to establish this great principle and to put it into execution, by building "anti-rolling tanks," as they were called, into the ship's structure and then filling these elongated tanks up to a certain critical point with sea water. These were expected to take on periodic oscillations from the ship's rolling motion, thus creating moments which would always be in opposition to the rolling and tend to reduce it. These tanks were actually built into two war vessels by the Admiralty, and experiments were undertaken with rather discouraging results, on two counts:

First, it was found that there were required a large tank and a large amount of water, representing quit an appreciable percentage of the total displacement of the ship—such a large

*Paper read before the Soc. of Naval Architects and Marine Engineers and published in the *International Marine Engineering.*

percentage, in fact, as to be prohibitive. The other point was the difficulty in maintaining proper phase relation between the natural period of the ship, the period of the water in the tank, and the period of the waves of the sea. More about this farther on. It will suffice to say that when this phase relation is not maintained, these tanks can easily become dangerous, tending to increase the roll rather than to reduce it.

Later the great English engineer, Sir John Thornycroft, undertook to accomplish the same result by a large horizontal pendulum operated hydraulically down in the hold of the ship; and the report of Sir William White—one of the Admiralty's greatest naval architects—on the actual operation of this device in a ship at sea in a storm (while Sir John and Sir William were dining together) makes one of the notable chapters in the early history of attempts at stabilization of ships. This stabilizer worked well at times, but it was found to have the same difficulty as the anti-rolling tanks, namely, in order to secure a sufficient reduction in roll to make the equipment commercial and practical, the weight of the equipment was prohibitive.

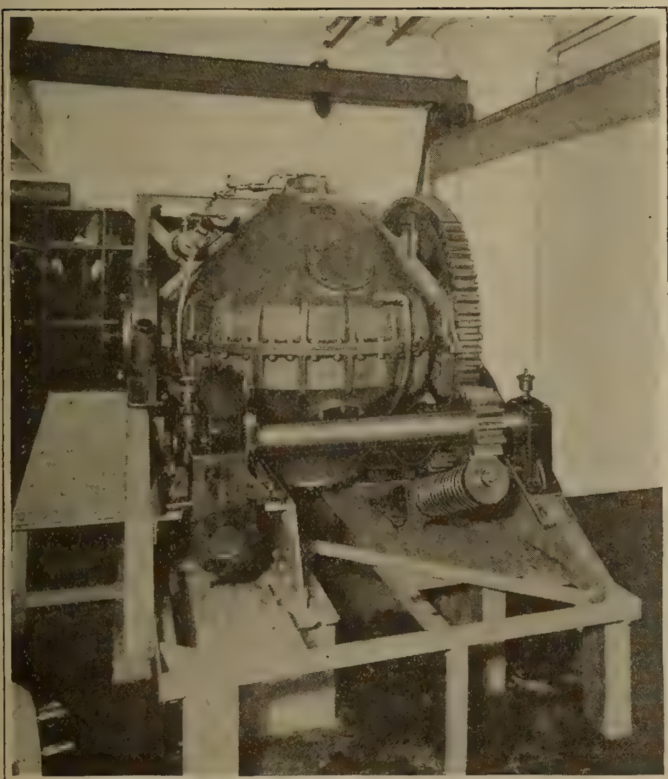
Later, Herr Frahm of Hamburg re-invented Sir Phillips' tanks, but though he made a contribution to the mathematical treatment of the subject and introduced some refinements in manual control valves and also in shape and contour, the tanks were found to be open to the same objections as those of Sir Phillip's.

Dr. Schlick, who had done such wonderful work in balancing marine engines, then came forward with his passive "gyrostat" or "Kreisel," as he called it. This was installed on a small torpedo boat and tested in the North sea. The Admiralty sent Sir William White, who, by the way, was a friend and admirer of Dr. Schlick, to report upon this device, and Dr. Schlick's rights were taken over by a leading English firm. The report is interesting. Sir William found this to be another device which depended for its action on the initial roll of the ship—that is, the quenching moments were dependent solely upon the ship's motion—and these would have been quite effective as a roll reducer had it not been for the same unavoidable lag in phase, which seriously impaired their efficiency. In any event, the combined difficulties, some of which are cited, were sufficient to prevent the adoption of this device, or, for large ships, even its serious consideration.

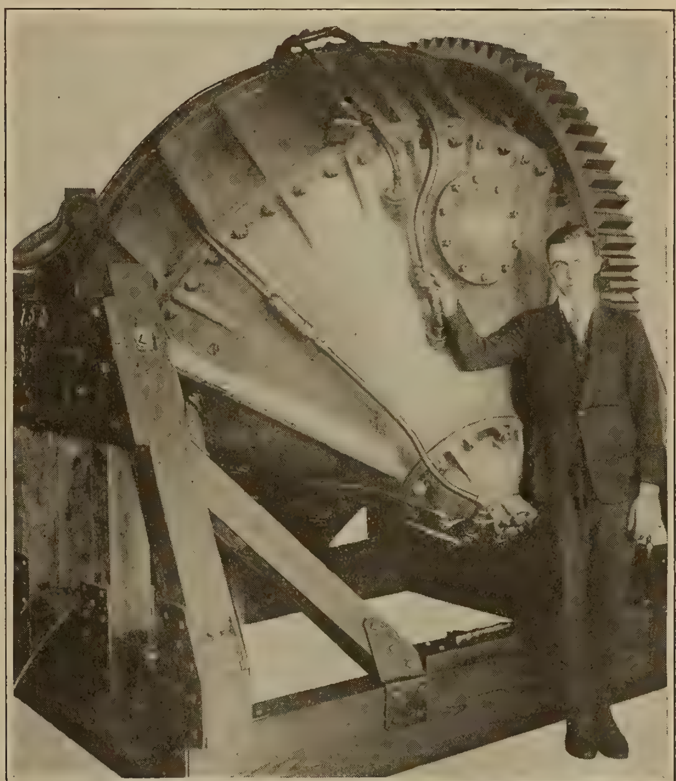
Later the action of anti-rolling tanks came under careful review by our own Taylor. This was before he became Admiral and Chief of the Bureau of Construction of our Navy, and while he still had charge of the big experimental tank at Washington, designed and constructed by him, and of the great collateral equipment that forms a part of the experimental and model department of the Navy. In this connection, Admiral Taylor, with his wonderful grasp of all this intricate phenomena, designed tanks that were unique; and to make his research and investigations complete he went at the matter in the most thorough manner, not confining his observations to one tank alone, but going to sea with a ship equipped with no less than three tanks. This was the most complete equipment, and the investigation was one of the most searching into the action of anti-rolling tanks that have ever been made the world over—as is characteristic of all of Admiral Taylor's work, which is conceived from a most complete and comprehensive standpoint and carried out in the most rigid and searching manner.

It is difficult to believe that the great art of naval architecture appreciates to the full the debt that it owes Admiral Taylor. Some little glimpse is had of the relation that this distinguished authority bears to the world-wide art, when we remember that at the time the "Hawk," warship of the British Admiralty, hit the "Olympic" near Southampton, within four hours of this memorable collision both sides had tried to reach Admiral Taylor by cable to retain him in the suit that they knew was imminent as the result of this accident. So the Government released Admiral Taylor to the Admiralty in order that important precedents might be established in the maritime world.

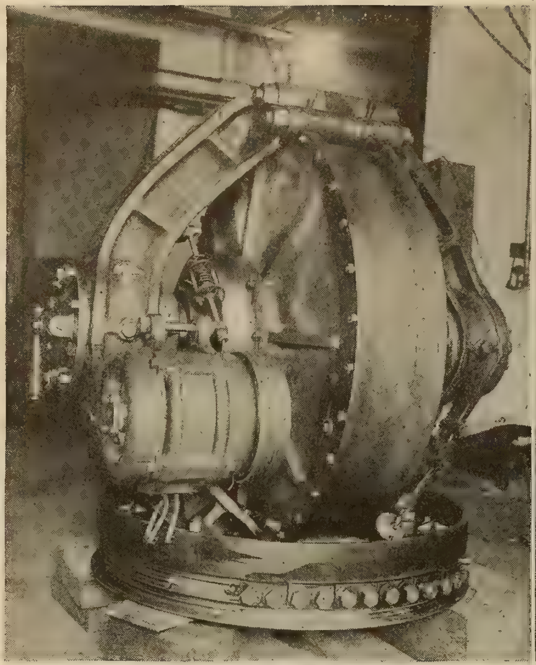
But to revert to Admiral Taylor's anti-rolling tank experiments. In this connection he reached certain conclusions, as he always does. These conclusions are interesting, as here we have the real crux of this whole matter. His verdict was that outside of the prohibitively large weights and extremely important athwartships space occupied by the tanks, neither the United States Navy, nor in fact any navy or marine, possessed the personnel requisite to keep the period in phase re-



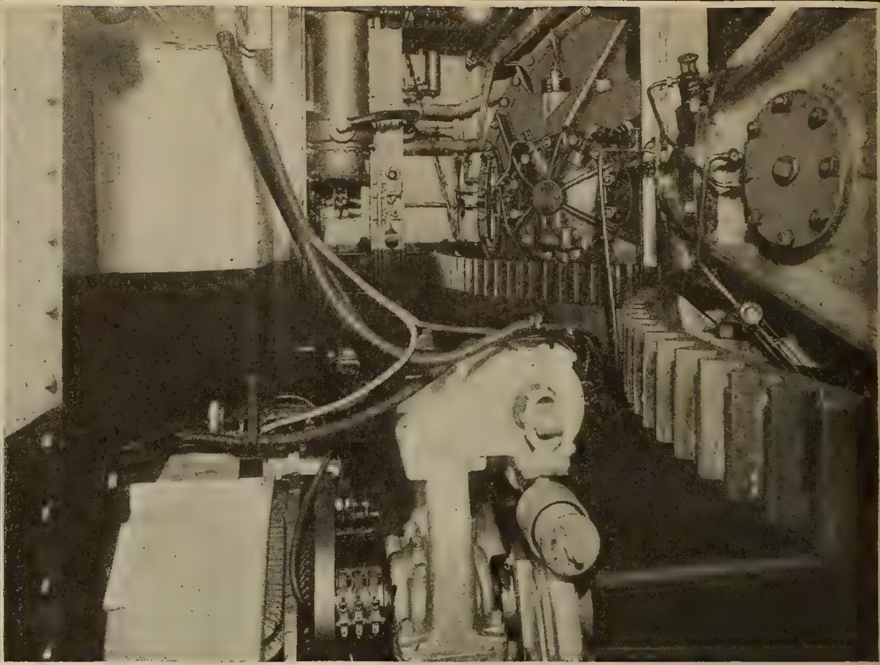
COMPLETE STABILIZER PLANT FOR 530-TON YACHT ASSEMBLED IN SHOP FOR TEST



STABILIZER FOR A LIGHT CRUISER MOUNTED IN SHIPPING FRAME



ORIGINAL ACTIVE STABILIZER INSTALLED ON THE DESTROYER WORDEN



STABILIZER ROOM ON U. S. S. HENDERSON. MAIN GYRO ON RIGHT, PRECESSION MOTOR IN FOREGROUND

lation with the natural period of the ship and also with the period of the sea. So at last this phase of the art has had the extremely great advantage of passing under critical review by probably the greatest living authority on these matters.

The difficulty with all of these attempts on this most important problem can be reduced to an extremely simple proposition: With all of these methods of attack, a pound weighs only a pound and its effectiveness is measurable in simple terms of the lever-arm of its application, or the distance from the center of oscillation of the ship at which the moments become effective. This is the reason for the excessive and even prohibitive weights necessarily present in all these methods of reducing the roll of ships.

Now what is wanted is not the reduction of roll, but the actual prevention of all rolling of ships, and it is just here that the powers and resources of the active gyroscope step in. For years engineers have observed the strange peregrinations of the gyroscope, but have failed to perceive the enormous powers that lie dormant in this simple apparatus, only awaiting the application of artificial "precession" to place it under perfect control and to render it abundantly serviceable for stabilizing even the largest ship. By the way, the larger the ship is, the easier it is to stabilize her.

In the gyro we have a most unusual illustration of the phenomena that Cicero classed among "real blessings"; that is, when nature's laws work to aid rather than to obstruct progress, by no means a too frequent occurrence in engineering. The gyro outclasses all other mechanisms in that, while its weight and cost vary as the cube of a lineal dimension, its stabilizing power varies no less than as the fifth power. This runs into a very great gain in gyro stabilizers for large ships.

Why is the gyroscope more available for solving this great problem than the tanks on the one hand or the great pendulum of Thornycroft on the other? The answer is simple. Whereas in the prior art, as we have stated, a pound is only a pound, in the gyroscope a new and extremely far-reaching situation is created. In arriving at the powers available to stabilize the ship with the gyro, every pound is multiplied by the velocity of the particle, so that a comparatively few pounds are actually capable of doing the work of tons. With the active gyro this is all held in phase, and, as described, is available for the important purpose of holding the ship free from even the beginnings of roll.

Those unfamiliar with the subject, and even some naval architects, have feared that the forces and stresses involved might endanger the ship's structure in case of a heavy storm. The exact nature and magnitude of these stresses are perfectly well understood and have now been brought under careful observation in quite a large number of equipments in actual service. We are therefore speaking from a wide range of accurate knowledge on this important item, and it will be interesting to know that the conclusions by the highest authorities are that a ship which freely rides the waves with its mast held vertical, being completely stabilized by the little gyro equipment in her hold, is subjected to less than one-fourth and often less than one-sixth of the very large strains present when it is allowed to roll under exactly the same storm and weather conditions and with the heading unchanged in the same sea. With the gyroscopic stabilizer equipment on board, we have the unique situation of being able instantly to throw it on or off, in action or out, at will, by stopping its slow precessional movements, so that we can observe exactly what happens under the two conditions and repeat each condition as often as we choose and hold each under complete observation as long as we choose, under any given sea or weather condition. And just such tests as these have been repeatedly made and studies pursued until they are well known and understood. Thus the presence of the stabilizer on the ship reduces and holds to a very low value the stresses and strains which in the case of an unstabilized ship in storms often rise to high and dangerous magnitudes.

Here again Admiral Taylor's work comes to the fore. The development of the active gyro stabilizer was aided materially through the encouragement given by this naval officer. He was among the first to appreciate the important results likely to follow the application of the active principle, *i. e.*, the ability to develop pure torque stresses in ships without change in loading or moving of weights or masses, and to direct these stresses and emplace them at will upon a ship independent of the state of motion of the ship itself and also independent of any particular position of the equipment upon or within the ship. This whole art certainly owes much to Admiral Taylor.

Everyone is familiar with the groanings, creakings, and weird noises that are always present in heavily laboring or rolling ships. These illustrate the stresses and strains to which she is being subjected. Imagine the sensation when the stabilizer is thrown into action and these sounds cease

forthwith, positively demonstrating that the heavy stresses have vanished. The stabilizer thus becomes one of the greatest safety devices yet invented imparting absolute security to the great hull and structure of the ship and materially prolonging its life. All of this, of course, is wholly outside of the

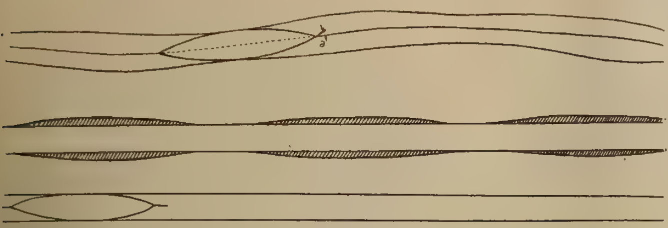


FIG. 1. LOSSES DUE TO HELM, ROLLING AND SINUOUS COURSE

The diagram at the top shows the path cut through water by stabilized vessel. The middle diagram shows that when the vessel is not stabilized it cuts a wider path as indicated above. The shaded area indicates proportional increase in power. The diagram at the bottom shows that further increase in power is required when the vessel yaws. The constant use of rudder absorbs power and tends to retard the vessel.

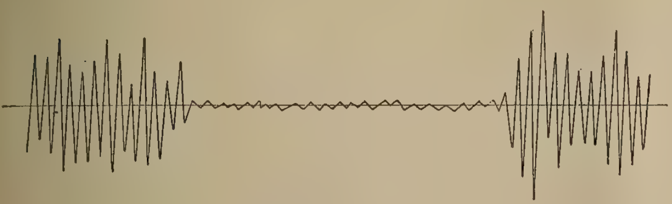


FIG. 2. CHARACTERISTIC STABILIZATION CURVE

consideration of comfort, which is one of the prime reasons for the installation on passenger ships.

In this connection it will be interesting from a technical standpoint to know that some time before the first stabilizer equipment was installed by the United States Navy, the great English naval architect, Sir William White, was brought to this country in consultation on this subject. He stated, after careful review of the facts, that from the naval architect's standpoint the strains introduced by the gyroscopic stabilizer in holding a vessel absolutely free from roll were insignificant, and that if we laid hold of a single frame of an ordinary steel ship we would have a factor of safety of about six, and furthermore that these strains and stresses were only a small fraction of those existing in the hull and general structure of a ship when rolling in a storm.

This great authority went further and stated something that our highest authorities in this country then doubted, namely, that as soon as a ship was stabilized in a storm and rolling was prevented, that ship would not ship seas, but her decks would immediately begin to be dry and would remain dry. Although we did not at the time believe that this could possibly be true, our universal experience since we have had these installations in operation demonstrates the absolute truth of the statement, as the result of many observations and experiments, incidentally showing the great insight of Sir William.

Even some excellent authorities, before actually having the unique and extremely interesting experience of being aboard a stabilized ship, have confused a stabilized ship with a dock, expecting the waves to pound the ship when stabilized, and it is with great surprise and satisfaction that they have repeatedly discovered just the reverse to be true. A stabilized ship invariably rides the sea, gradually rising and falling with the sea with a wonderful degree of gentleness. Her masts quickly come to the vertical, and all pounding and splashing disappear as soon as stabilizing sets in.

Other facts have been learned from the performance of the stabilizer in heavy weather. It is found actually to contribute a number of definite economies in the operation of the ship. Anyone who has ever undertaken to pilot a heavily rolling ship and to hold her to her course has realized the enormous amount of "helm" that is constantly required, and the resulting very sinuous course that the ship takes in spite of the best efforts the helmsman can make under these conditions. The diagrams in Fig. 1 graphically illustrate this and other features.

No pains have been spared in studying this important phase of the contribution of the stabilizer. The gyro compass with its enormous directive power enables automatic records to be made of the most minute orientation of the ship. These have been secured and also simultaneous graphic records of the amount of helm being used by the ship, also automatic, so that there could be no question as to exactly what was happening. The study of these records has been full of interest, developing an accurate method of analyzing and aiding to establish the losses under this division.

Fig. 2 shows a characteristic stabilization curve and Figs. 3 and 4 are helm records.

Operating engineers and naval architects know that even

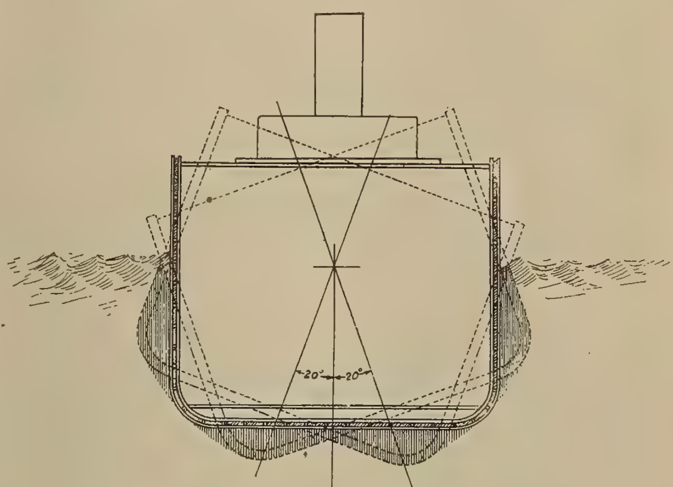


FIG. 5. RELATION OF POWER CONSUMPTION TO ROLL

The shaded area shows extra water disturbed. For a 37,000-ton vessel at 22 knots this means a loss of 3,100 horse-power.

a very slight amount of "helm" acts as a tremendous retarder in the forward progress of the ship, and especially is this emphasized when a very large amount of helm has to

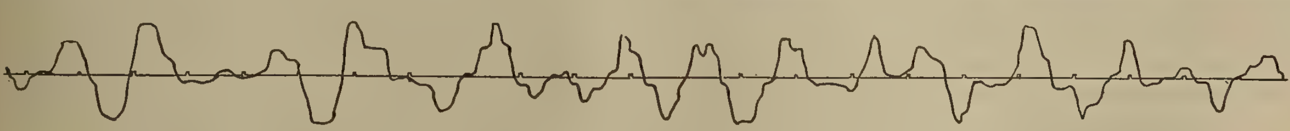


FIG. 3. AUTOMATIC RECORD; HELM REQUIRED, SHIP NOT ROLLING

Straight line indicates rudder center with one-minute intervals as jogs.

FIG. 4. AUTOMATIC RECORD; HELM REQUIRED, SHIP ROLLING HEAVILY

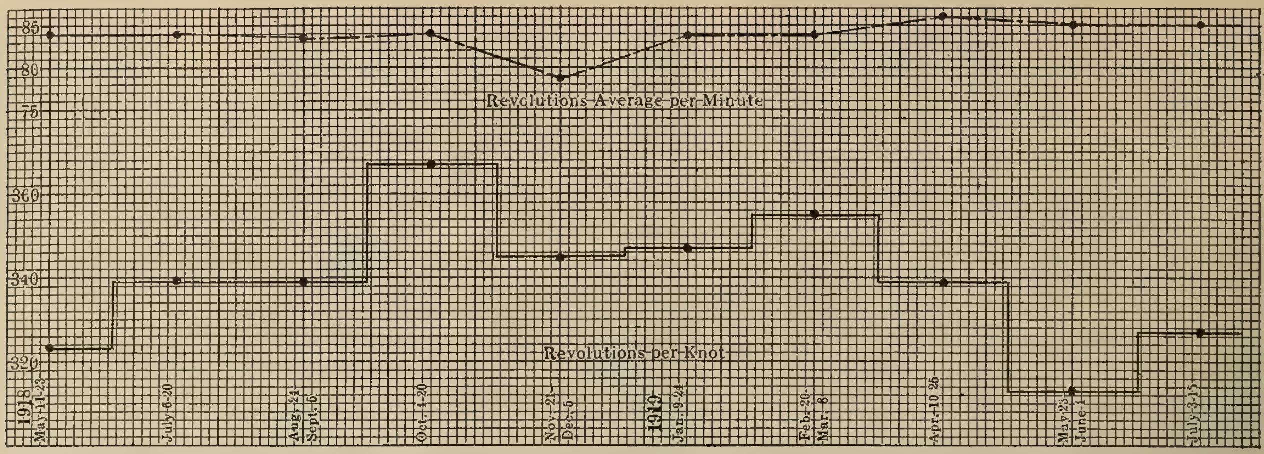


FIG. 6. DATA FROM ENGINEER'S LOG OF CARGO AND PASSENGER VESSEL SHOWING RETARDATION BY WEATHER CONDITIONS IN WINTER MONTHS

be constantly employed. This slows down the ship, uselessly wasting a great deal of the propulsive power of her engines. Again, the sinuous course that is invariably steered by a wallowing ship causes it to travel a considerable extra distance, always accompanied with a "bad angle of attack," causing a large extra power consumption. A stabilized ship is practically self-steering. This comes as a sort of a bi-product of stabilization, the stabilized ship requiring practically no helm, regardless of weather.

But there is a still greater source of power waste in rolling ships. As the hull constantly oscillates back and forth, its form-lines encounter and constantly displace laterally, with extra friction of impact, hundreds and even thousands of tons of water, and this persists, going forward with every roll. This, in connection with the extra wetted surface involved, added to the extra stream-line losses and skin friction impingement, especially when bilge keels are present, amounts to losses of very great magnitude in terms of actual horsepower wasted. Model experiments and resulting calculations indicate that these losses are much higher than have been supposed. Fig. 5 graphically expresses by the shaded area the tremendous increase in volume of water disturbed by a rolling vessel. For a 15,000-ton vessel at 18 knots—away inside the maximum roll—this loss may easily reach from 1,000 to 1,200 horse-power, and this power is absolutely dissipated and wasted.

Just here the stabilizer steps in with a saving of nearly all of this—practically the entire amount, minus the small and comparatively insignificant quantity of power that is required to keep the gyro wheel spinning in a vacuum. In the course of a very few voyages this power saving in terms of fuel saving amounts to enough to pay for the entire stabilizing equipment.

Very full corroboration of this is found in the service performance of a fast passenger and cargo ship, by taking ten consecutive trips over the same course in the same direction with almost identical load conditions and under conditions of constant propeller revolutions. These trips are sufficiently long, 4,600 miles, to be convincing in the results shown. This data has been plotted in revolutions per knot (see Fig. 6) and gives interesting and positive indication of the retardation of the ship owing to weather conditions. A very great amount of the losses in headway due to the retardation effect of the disturbances discussed above will be entirely eliminated by full stabilization. Let us examine what this means in dollars. Suppose the operating expense per 24 hours to be $6,000. The extra expense—that is, the expense over and above the average—in the stormy months amounts to not far from $100,000. This, taken with the amount saved through elimination of bilge keel losses, develops an earning capacity of the stabilizer of not far from 100 per cent per annum. All of this is over and above the many other important gains, both direct and indirect, resulting from the stabilizer installation.

The stabilizer achieves another economy of very great significance to both the operator and the passengers of fast ships. This is the practical avoidance of the necessity for slowing down ships in stormy weather or when heavy seas prevail, the ships being able to make practically the same time under storm conditions. This has been repeatedly demonstrated and is a result so startling that, when first experienced, it has often been claimed as an original discovery by the skippers of stabilized ships.

So insignificant are the stresses required to prevent all rolling that it is interesting to compare them with, or to state them in terms of the specific loading permitted by the underwriters. Take a concrete case of the transport Henderson, of 10,000 tons displacement, 488 feet length, with maximum beam of 48 feet and draught of 19 feet 9 inches—the allowable load per running foot for the section where the stabilizer is located is 14.5 tons. The load due to the weight of the stabilizer plus the maximum gyroscopic stabilizing moments, figured as load upon the vessel, is at maximum only 10 tons, and with average stabilizing moments about 6 tons per running foot. In other words, the stabilizer loads are much less than normal cargo loads. Some of the vessels carrying heavy machinery to France were loaded as high as 28 tons per running foot.

Another definite advantage secured by the stabilizer is the elimination of the bilge keels. Dealing only as they do with "V" square, they can never be of service other than in the heaviest rolling—at all other times they are a positive menace. The well-known drag of bilge keels in perfectly calm weather is not only ever present but represents positive losses, even in excess of those calculated. This has now been positively observed in the case of a large 20-knot ship, the performance with and without bilge keels for the same shaft revolutions, loading and trim being known. Moreover, a ship is never trimmed very accurately longitudinally, giving the bilge keels

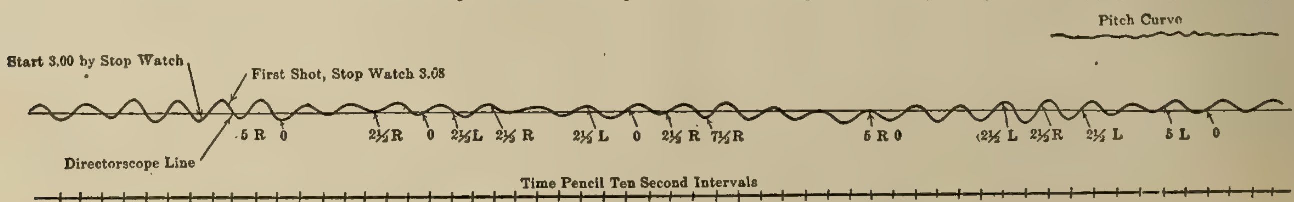


FIG. 7. AUTOMATIC CONSTANT ROLL IMPARTED TO U. S. S. HENDERSON AT SEA

a frontal attack component with the attendant eddies, consuming additional power of no small magnitude.

In rough weather the bilge keels afford an extra opportunity for the waves to lay hold of the vessel in rolling. Recently it has been definitely determined that the power required by bilge keels under the condition of pitching, even in a moderate sea, increases the propelling power to a point much beyond what had been supposed. In the case of a 10,000-ton vessel with standard keels, even with moderate pitching, an increased propelling power of about 9 per cent has been observed. In a stabilized ship it is possible to eliminate bilge keels. There should be no hesitancy in omitting keels, as an exceptionally large and successful fast passenger ship has been operated without bilge keels for years.

A reduction in stresses of the propelling machinery of a stabilized ship represents another important gain, especially in the case of twin-screw vessels where the windward propeller is held very much more satisfactorily to its duty—not only saving power but preventing the racking strains due to overspeeding when the screws are "rolled out." The efficiency of a propeller falls off abruptly as its blades even approach the surface, especially where the dip of the waves allows the slightest aëration of the water. For efficiency a propeller requires to be kept down in stiff water.

Prevention of deterioration in cargo applies especially to ships carrying live stock. Figures have been furnished by a concern transporting horses during the war showing that, in a heavy storm during a single trip, their losses per trip often amounted to $30,000 or $40,000, a sum sufficient in a short period to equip the vessel with a stabilizer.

The ability to roll the ship has proved in actual experience to be important in case of emergency to free the vessel from sand and mud banks, by opening the contracting crevices and gradually liquifying the encumbent mass. This has been discussed in a former paper, also the field of the active gyro in rolling ice-breakers and preventing them from freezing in when cutting through rivers and harbors during the winter months. The most important use for rolling however is as an aid to gunnery.

As outlined, we have been accumulating a large amount of actual sea experience with various sized equipments. The Government has been of the greatest assistance in encouraging the development. The war has seriously interfered with the work, but even during this period the Navy has allowed us to complete the largest gyro equipment yet attempted, and though the installation has been retarded by the ship's being in constant transport service, this fact has offered additional opportunity for final testing. One of the engravings shows a corner of the gyro room on the Henderson with the precession motor in the foreground, and another illustration shows the little control room with the rotary for generating A. C. current for spinning the gyros in the background. Directly in front of the rotary converter is the vertical gudgeon bearing which transmits the stabilizing moments through the ordinary steel decking to the ship's structure. This ordinary steel decking is found to carry the stabilizing moments with a large factor of safety. In the foreground is the special control gyro for the ordnance tests. In this case the gyro may operate in a single period successively as a stabilizer or as rolling equipment. Fig. 7 shows a curve of the Henderson automatically rolled by her special equipment when under full headway.

This ship has operated with as high as 11,500 tons' displacement, and the stabilizer has been repeatedly operated under overload conditions without difficulty, the journals running with perfect temperature control under the heaviest duty, including overload conditions. Even different lubricants have been tried, all giving about the same results; in fact, the plant, since the journals have been worked in, has operated normally in service, and the records show that the guaranteed stabilizing moments have been easily developed.

This equipment has undergone additional protracted tests as an ordnance fitting, reaching results in this connection which are very interesting. The exacting nature of these tests and their severity have contributed in no small measure to another extremely interesting result as follows: The complete knowledge we now have of the behavior of these equipments and the measured results and records have placed us in a position to guarantee unqualifiedly the stabilization of practically any ship to accurate specification and also the equipment by means of which this important result is secured.

The Trans-Sahara Railroad

Technical Features of Its Construction

MUCH interest is being felt by France in the projected railroad lines across the desert of Sahara, between south Algeria and the French territory in western Africa. On the 27th of September, 1919, *Le Génie Civil* (Paris), published maps of Africa indicating the railroads already constructed and the trans-African lines which had been proposed before the war. We reproduce these maps with a summary of the accompanying article.

Le Génie Civil has already published an account of the two principal trans-Saharan railroad lines—first that of the Chief Engineer of Roads and Bridges, Souleyre, who projected a line starting from Biskra and running through Touggourt and In-Selah, towards Timbuctoo, with a branch line connecting with Lake Tchad; and secondly the plan proposed by M. André Berthelot, a brief resumé of which appeared in *Le Génie Civil* for July 25, 1914, whose point of departure was Colomb-Béchar, the terminus being South-Oranais (Fig. 1).

Still other promoters projected a more extended program of communication between Algiers, the Niger, the Belgian Congo and British East Africa, by branch lines running respectively through the region of Timbuctoo, the terminus (Kano) of the Nigerian railroad, then Stanleyville, along the Congo River, and finally, Port Florence on Lake Victoria (the terminus of the British line, whose other end is at Mombassa, a port on the Indian Ocean).

Thus it was proposed to connect Algeria (and consequently Morocco and Tunisia) first with western and equatorial Africa whose valuable products (particularly the mineral wealth of Katanga in the Belgian Congo) hold out flattering prospects; and finally, by an agreement with the future Cape to Cairo line, with the vast and prosperous regions of South Africa.

Still other projects, scarcely less impressive, have been a matter of recent agitation: the Paris-Madrid-Tangier-Dakar line, to which we shall refer further on, and that of the Trans-Soudan line started from Dakar (and from Conakry) and running towards Fort-Lamy and Khartoum, with its terminus at Port Soudan and Djibouti on the Red Sea, recommended by M. Tilho.

The new economic conditions caused by the war do not permit the realization, at any rate in the near future, of projects having so large a scope; when even the reconstruction of a few hundred kilometers of the lines destroyed in the north and the east of France is, at present, a difficult task, and the service of our main lines is so uncertain that the Paris-Lyons express is commonly many hours late, etc., etc., it is easy to see that the French government cannot undertake such an onerous enterprise.

Nevertheless, the future of our immense African possessions must be kept in mind, and it is permissible to indicate a few land-marks which may facilitate the labors of the next gen-

FIG. 1. MAP OF AFRICA SHOWING EXISTING RAILROAD LINES AND LINES PROJECTED

FIG. 2. MAP OF WEST AFRICA SHOWING THE COURSE OF THE TRANS-SAHARAN LINE PROPOSED BY M. GODEFROY

eration. It is this sort of thing which lends interest to two memoirs recently published by Lieut. Colonel Godefroy, the director of the Biskra-Touggourt line and by M. L. Durandeau, director of the Bureau of Technical works in the territory of South Algeria. After passing in review the economic conditions and the present state of affairs in our African colonies . . . Lieut.-Colonel Godefroy tackles the question of the trans-Sahara, properly so designated. . . . He justly considers that the ambitious Trans-African projects contemplating a continental and trans-continental traffic connecting London and Paris with Central Africa, on the one hand, by way of Marseilles, Algiers, the Belgian Congo, and the Great Lakes, and with South America on the other, by way of Marselles, Algiers, the loop of the Niger and the transit from Dakar to Pernambuco, are not at present feasible. . . .

The same conclusion was reached by M. Suss, who read an article before the Society of Civil Engineers on July 15th of last year, concerning the project of a connection between Paris-Tangier-Dakar by a new line of standard gage, traversing the whole of Spain from Irun to Algeciras by way of Madrid, passing under the Straits of Gibraltar through a 40-kilometer tunnel, or more simply perhaps by means of ferry-boats similar to those which are operated successfully both in Scandinavian countries and between France and England, and running directly from Tangier to Dakar by way of Fez (3,500 kilometers), thus securing a fast service from Europe to South America by way of Dakar. M. Godefroy considers that if it is desired to create a connection between Algeria and the Cape to Cairo line, it will be more advisable, instead of seeking to form a junction with this line in the middle of Africa, to connect with it at Cairo by a line running through Fez-Algiers-Tunis-Tripoli and the littoral of the Tripolitan and Cyrenaïc territory. Besides this general traffic such a line would have the advantage of serving as a means of transport for the great numbers of Moslems who annually make a pilgrimage to Mecca, and whose numbers fill entire ships, and for whose convenience the Turkish government built the line from Damascus to Medina in 1908.

A portion of the Fez-Cairo line is already in existence as far as Gabès on the one side and from Daba to Cairo by way of Alexandria on the other side; furthermore, the strategic line built by the British to supply their expeditionary force in Palestine could be easily prolonged to the Mecca line.

M. Godefroy is more interested, however, in the idea of an actual Trans-Sahara line having for its object the connection of South Algeria with the loop of the Niger at Tosaye, a point in the vicinity of Bamba and of Bourem (Fig. 2) where it is expected that a junction will be made with the future railroads of French West Africa.

The projected line whose construction he advises starts from Touggourt, the present terminus of the Algerian system (the Algiers-Constantine-Biskra-Touggourt lines); it descends by way of Ouargla (the date-bearing region), and In-Salah, traverses the Tidikelt and the Adrar, terminating at Bourem, or about 2,360 km. in round numbers. At the chosen junction at Tosaye the Niger is confined between two steep banks where the construction of a bridge would present the minimum of difficulty. By adding to this length that of the Algiers-Touggourt line (640 km.) the complete trajectory from Algiers to the Niger would represent 3,000 km.

It may be added that at the present time the line proposed is outlined as far as In-Salah by the automobile tracks recently built beyond Touggourt.

ELEMENTS OF THE TRAFFIC.

Travelers.—French West Africa might furnish numerous passengers in Algeria and in Tunisia to supply the shortage of labor in the mines and in agriculture; this source might yield a considerable and almost constant current of natives between the north and the south. Passengers of a better class would evidently be but few in numbers, the majority being officials provided with free transports of travelling at reduced rates. On the other hand the Sahara line would readily take the place of maritime passage for mail and parcel post.

Various Products.—The traffic in merchandise would consist mainly in rice from the Soudan, cattle on foot or refrigerated meat from the loop of the Niger bound north and south-bound, of wheat, fruit, Algerian dates, fabrics and manufactured products, as well as tools, etc., from Europe. . . .

Technical Conditions of Construction.—The two brochures cited above are particularly interesting in their presentation of the technical conditions involved. . . . We give by preference a resumé of M. Durandeau's remarks, since while agreeing with those of Godefroy they enter more into detail. . . .

Width of Gage.—The standard gage has been recommended by Souleyre and Berthelot; it exists on only a part of the Algerian system, but the South Oranais lines have a gage of 1.05 m., those of South Algeria a gage of 1 m.: Since a

transfer of freight is required already, for this reason, it would appear to be natural to continue with one of these widths, the Sahara line being the immediate prolongation of one or the other of these systems, according to whether the line started from Touggourt or eventually from Colomb-Bechar. Economical reasons practically impose this solution, which furthermore presents no grave inconveniences. It is quite erroneous to connect the idea of a narrow gage road too readily with that of a light traffic road . . . certain narrow gage roads, in fact, carry very heavy traffic: for example, the mining road of the Zaccar, having a gage of 0.75 m., which annually carries to the Miliana station on the Algerian P. L. M. more than 100,000 tons of minerals; moreover, in former German East Africa the Otavi line, which has a gage of only 0.60 m., but is 671 km. long, carried 107,000 tons in 1913. Furthermore, a narrow gage line, having curves with a minimum radius of 500 m. and grades of a maximum of 10 per cent lends itself with perfect ease to high rates of speed, provided the track is strong, has cross-ties sufficiently close together, and particularly is provided with heavy rails of sufficient length.

Furthermore, if the amount of traffic proves large enough in the course of a few years to justify a change of the narrow gage into a gage having a width of 1.44 m., such a change could readily be made without interrupting the service by first making a gradual preparation for the increasing width of the road-bed and the bridges, and then by inserting between the present cross-ties those of a standard length to which the new rails are attached. In this manner the change from the narrow gage could be made at leisure. The apparatus required, which are, on the whole, few in number, could be prepared in advance, placed alongside the laying point, and put in place at the time the service was changed.

M. Durandeau proposes the laying of a track with double-headed rails in 20 m. sections, weighing 35 km. per meter, resting upon rail-chairs and upon cedar ties measuring 2.20 m. by 0.24 m. by 0.14 m., or else upon metal ties 45 km. each in weight and 1.90 m. in length. Such a track would be able to support loads of 17 tons per axle-kilometer at speeds of 60 km. per hour.

The choice of the double headed rails mounted upon rail-chairs is justified by the necessity for raising the track as high as possible above the ballast. This is desirable in the first place, in order to facilitate the passage of the fine sand driven by the wind between the ties from one side to the other of the line, thus diminishing the danger of having the rails covered with sand, and consequently to protect the rails as much as possible from the dangerous corrosion due to the saline character of the ground throughout a large part of the territory to be traversed; this ground contains chlorides and sulfates which, under the influence of the very considerable variation in the humidity of the ground, set free acids which attack the rails and fish plates very rapidly. It is evident that metal ties are impossible in regions of this character.

In order to prevent the drifting of sand over the switches, a circumstance which has often caused accidents on the lines of South Algeria, it is a good plan not only to support the rails on rail chains but also to place the ties upon a bed composed of other ties running parallel to the track and joining together. If this be done the sand will run between the rails and the ties and will fall upon the aforesaid bed whence it is rapidly driven by the wind.

The question of the width of the road-bed is of primary importance for a track through the Sahara Desert. The road-bed lies most often upon sandy ground which is eroded by the wind; the slopes of embankments are diminished on the windward side so that little by little the road-bed decreases in width up to the ends of the ties, and in cuts the sand frequently drifts over the track.

Furthermore ballast made of broken stone of good quality is very expensive because of the enormous quantities required and the considerable distance over which it must be transported, while ballast made of crushed gypsum, which can be obtained upon the spot, quickly crumbles, thus injuring the road-bed, the rails and even the health of the crews.

It is advisable in laying out the track to avoid the immediate proximity of sand dunes so that it will be possible to employ some method of fixing those dunes which threaten to invade the track before they become dangerous. This stabilization may be accomplished by planting tamarinds or by driving piles in them.

The line along which the necessary stations are not very numerous should be laid out rather with a view to avoiding grades than with the idea of procuring an indefinite straight alinement. The reason for this is that by thus preserving curves of large radius, the visibility of the track and the maximum of the speed attainable can be maintained almost as well as a long straight line, and one will, furthermore, be able to save the extra energy required by up grades or wasted unnecessarily in braking the train on down grades.

Masonry.—The serious inconvenience referred to with respect to the possible corrosion of the rails also affects mortars made of lime or of cement to which the saline nature of the argillaceous territory of the great *chotts* (lakes which have become nearly dry) or of the territory containing gypsum, likewise very abundant, is distinctly injurious.

With respect to this the experiments in masonry work of the South Constantine lines are unhappily very convincing—the alternations of heat and of cold, of drought and of damp, exert a very unfavorable influence upon the resistance of elements, especially since they are themselves unstable as respects chemical composition and since they are often applied by careless and incompetent workmen.

M. Durandeau also advises against the use of hydraulic binding substances, making use preferably (as in the case of a bridge on the Biskra-Touggourt line) of hewn stone and of cedar, which is abundant in Algeria, and which is not subject to decay; in default of this he recommends masonry built of dry stones, and finally the employment of thick lime when mortar is indispensable.

In the Sahara, where there is a lack of building materials, one finds only rubble made of gypsum, which can be conveniently used for all masonry, together with a mortar made of thick lime and the sand of the locality; the Biskra- Touggourt line constructions are built in this manner and have proved satisfactory.

Mode of Traction.—The scarcity and poor quality of the water obtainable in the desert areas of the Sahara precludes the use of steam for motive power. During the work of construction there is no time to make the necessary search for subterranean waters without retarding the progress of the work; then, too, the expense of bringing fuel from Europe would be prohibitive. Even in ordinary established traffic it is difficult to employ steam engines.

It appears preferable to lay plans for using either motor tractors of the Diesel or Still type, or else electric traction by means of a current obtained from groups of motors of the same kind. This subject requires some study since all the required details are not yet understood. However, the rapid progress of mechanics and of electricity leads us confidently to expect that the problem will be solved in due time. . . .

THE SHRINKAGE OF VENEER.

According to present practice, logs which are to be cut into veneer are either steamed or soaked in hot or boiling water for several hours to soften the wood. The claim is sometimes made that the veneer from boiled logs is likely to shrink and swell less with changing moisture content than the veneer from steamed logs. This point was made the subject of investigation by the Forest Products Laboratory.

Although these tests were crude, they indicate that the shrinkage of veneer from boiled and steamed logs is practically the same.

KINGS BAY FROM COAL HARBOR, THE MINING SETTLEMENT OF THE NORWEGIAN KINGS BAY COAL COMPANY ON ITS SOUTHERN SHORE

On the right is shown the terminus of the most northerly railroad in the world (78° 56′ N.) The line, 1½ miles long and of 36-inch gage, carries the coal from the mine to the harbor.

The Norwegians in Spitsbergen*

Their Rightful Claims to Sovereignty of This Archipelago

By Charles Rabot

Société de Géographie de Paris

Special interest attaches to this article in view of the fact that the Supreme Council of the Peace Conference at Paris on November 21 approved the text of an agreement granting political suzerainty over the Spitsbergen archipelago to Norway.—EDITOR.

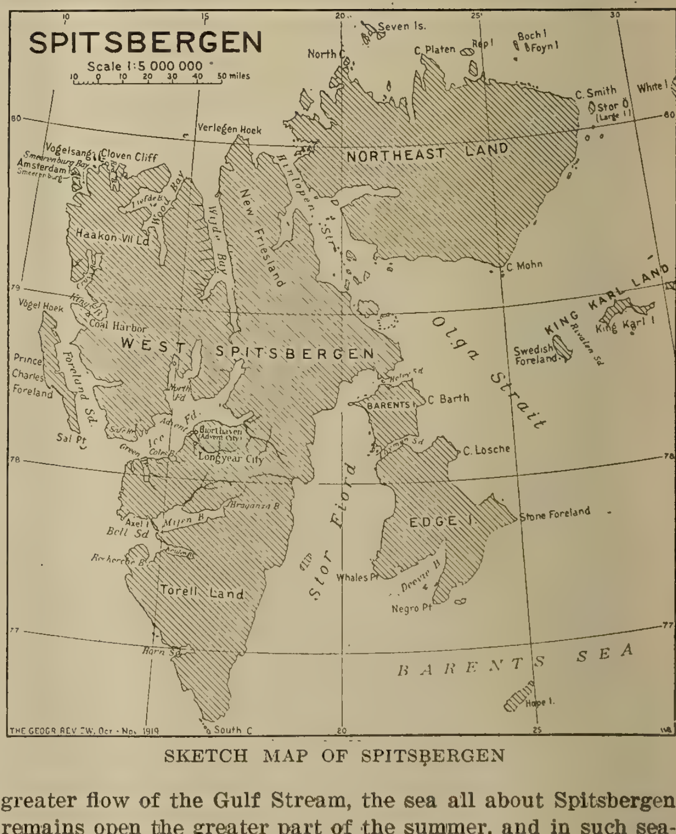
SEVERAL papers concerning Spitsbergen have recently been published, but they are incomplete and inaccurate, their authors being unaware of the great work done by the Norwegians in this archipelago and of the recent historical research work of the Dutch. It may therefore be useful to attempt to present a comprehensive account of geographical progress in Spitsbergen and of the industrial development of this polar land as well as its political history.

ICE CONDITIONS ON SPITSBERGEN COASTS.

Owing to the climatic effects of a branch of the Gulf Stream, the western coast of Spitsbergen and the westernmost part of its northern coast are usually ice-free from July to October. Sometimes the western coast is open until December. In 1892, on July 29, 30, and 31, between Jan Mayen and Ice Fiord, I did not see a single cake of ice. Thanks to these circumstances tourist-crowded liners in service before the war used to push up from the northwestern corner of Spitsbergen as far as the eightieth parallel to let their passengers enjoy a view of the polar pack. In no other part of the world can one reach so high a latitude in open water.

By contrast, a polar current flowing past eastern Spitsbergen, carrying a large amount of ice, blocks the eastern coast of Northeast Land, Barents Island, and Edge Island. Off the southern coast of the last-named island a branch of this current takes a westerly direction, rounds South Cape, and runs northward between the Gulf Stream and the western coast of Spitsbergen, carrying masses of ice which generally disappear by early summer. Such is the normal state of the ice, but it may be interfered with by the winds. In spring and summer northern and eastern winds prevail, the polar pack drifts southward and closes the generally open waters off the northern coast, while the eastern ice drifts southward also, opening Stor Fiord and the sea off the eastern coasts of Northeast Land, Barents Island, and Edge Island. A great deal of this ice skirts South Cape and arrives on the western coast at the southern point of Prince Charles Foreland. In 1915 so much eastern ice gathered on the western coast that Bell Sound and Ice Fiord were blocked and navigation was very difficult until the end of August. Probably not since the discovery of Spitsbergen, certainly not in the last fifty years, had the western coast been so obstructed by ice.

It also happens, but very rarely, that owing perhaps to the greater flow of the Gulf Stream, the sea all about Spitsbergen remains open the greater part of the summer, and in such seasons the circumnavigation of the archipelago becomes possible. This was the case in 1918 and, before that, in 1886, 1887, 1898, and 1899.



SKETCH MAP OF SPITSBERGEN

*Reprinted from the *Geographical Review* for October-November, 1919, published by the American Geographical Society, Broadway at 156th Street, New York. Photographs loaned by the *Geographical Review*.

PANORAMA FROM BEN NEVIS, A SUMMIT 913 METERS HIGH SOUTHEAST OF RED BAY, NORTHERN WEST SPITSBERGEN
The view, which extends from south to northwest, shows practically the whole extent of the Grand Glacier, which ends in Red Bay on the right. (Photo by Captain Gunnar Isachsen.)

HISTORY OF EXPLORATION.

The story of the geographical exploration of Spitsbergen can be divided into three periods: (1) the Dutch-English, which lasted until the beginning of the eighteenth century; (2) the Norwegian-Swedish, between the end of the eighteenth century and the opening of the twentieth century; (3) the Norwegian, since 1906.

DUTCH-ENGLISH PERIOD.

The old Icelandic annals regarding the discovery of Spitsbergen by Norwegians in the eleventh century are vague, and the journey of Willem Barents in 1596 is considered as the first authenticated voyage to this Arctic land. The celebrated Dutch seaman visited only the western coast and a part of the northern coast of the main island, and the discovery of the other islands has been credited to English "adventurers" of the Muscovy Company. But this claim must be revised. The globe of the Dutch cosmographer Plancius, engraved in 1612 and newly discovered by Dr. F. C. Wieder, delineates the northern coast beyond Hinlopen Strait, the Seven Islands, the western and southern coasts of Edge Island, and Hope Island. Thus, previous to the English, even "before 1614 the entire circumference of Spitsbergen was known to the Dutch, except the vicinity of Heley Sound (Helis Sound) and the east coast of North-East Land and Edge Island, so that the Dutch may rightly be called the discoverers of the entire Spitsbergen group."[1]

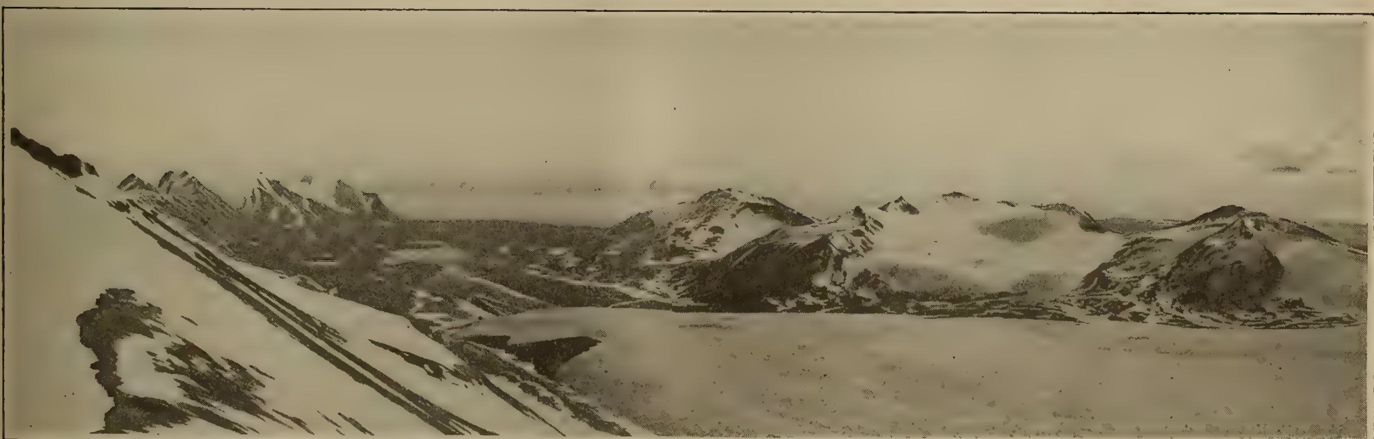
About the middle of the seventeenth century, while the English whale fishery declined, the Dutch whaling industry had a rapid development, which was of great advantage to geography. Returning home, the Dutch whalers gave to the cosmographers of Amsterdam information concerning Spitsbergen, so that in Holland there was continuous and uninterrupted progress in the cartography of these polar islands. From 1594 to 1892, according to Dr. Wieder, more than two hundred maps of Spitsbergen were published in the Netherlands. To the Dutch we are indebted for the first cartographical documentation concerning these islands. During two and a half centuries the Dutch were the masters of the cartography of Spitsbergen.

NORWEGIAN-SWEDISH PERIOD.

Toward the end of the eighteenth century the Dutch whale fishery declined, and the Norwegians arrived at Spitsbergen in order to hunt the walrus, seal, polar bear, and reindeer in summer. Their activity was at that time limited to the western coast and to the easily accessible part of the northern coast. In 1827 B. M. Keilhau, professor at the University of Christiania, chartered one of these sealing vessels and paid a short visit to Bear Island and Spitsbergen. This was one of the first scientific expeditions to these islands and one of the most successful. The geological, paleontological, and botanical studies which Keilhau had the opportunity of making during his voyage are fundamental. In 1837 the Swedish professor S. L. Lovén also made a scientific trip to the western coast in a Norwegian vessel.

In 1858 the second chapter of the history of Spitsbergen opens with the geographical exploration of the archipelago both by Swedish scientific expeditions and by Norwegian walrus hunters. From 1858 to 1908 twenty Swedish expedi-

[1]The Dutch Discovery and Mapping of Spitsbergen (1596-1829). Edited by order of the Dutch Minister for Foreign Affairs by Dr. F. C. Wieder. Published by the Netherland Ministry for Foreign Affairs and the Royal Dutch Geographical Society, Amsterdam, 1919. This splendid volume contains the reproduction of 83 maps of Spitsbergen between 1596 and 1829.



LOOKING SOUTH DOWN ERDMANN GLACIER (RIGHT AND CENTER FOREGROUND) AND ITS OUTLET VALLEY TO THE FURTHER SHORE OF BELL SOUND (IN THE BACKGROUND).
The massif on the right is Mt. Conway, that on the left, South Halland Ridge. (Photo by Engineer Koller.)

tions went to Spitsbergen under the leadership of scientists like Otto Torell, A. E. Nordenskiöld, A. G. Nathorst, Baron Gerard de Geer and others. Besides valuable scientific studies they published in 1865 the first chart of the archipelago based on surveys. This chart has been the basis for later ones representing fresh discoveries. The British Admiralty's chart, reproduces the results of the Swedish surveys.

DISCOVERIES BY NORWEGIAN WALRUS HUNTERS.

During the second half of the nineteenth century no Norwegian scientist took part in the exploration of Spitsbergen.

LONGYEAR CITY IN SUMMER

Nevertheless important discoveries were made by Norwegians. About the year 1850 game became scare in the easily accessible parts of Spitsbergen, and Norwegian walrus hunters sought new grounds in the generally ice-blocked waters stretching northward and eastward and made important discoveries in the hitherto unknown eastern parts of Spitsbergen.[2]

The first step in this direction was taken in 1847, when Captain Lund navigated Thymen Sound, between Edge Island and Barents Island, for the first time. At that time Barents Island was not known to be an island; it was represented as a large foreland of West Spitsbergen, and Heley Sound was shown as a fiord. In 1858 Captain Johan Nilsen crossed this inlet from sea to sea, demonstrating the supposed fiord to be a strait. By this discovery the features of eastern Spitsbergen were also completely changed. In 1859 another Norwegian seal hunter, the well-known Elling Carlsen, cruising eastward of Edge and Barents Islands, found himself near an unknown land. This was the islands now named King Karl Land but then identified with Giles Land, an island seen in 1707 by Commander Giles, the position of which remained uncertain at that date. Three years later, in 1861, Carlsen for the first time circumnavigated the whole archipelago—a splendid achievement. During this cruise the true nature of Northeast Land was ascertained. It was discovered that the eastern coast of this large island is entirely occupied by a great glacier discharging into the sea and forming the eastern outflow of an inland-ice mass which covers the whole island. In 1864, off the eastern coast of Northeast Land, another gallant Norwegian hunter, Tobiesen, rediscovered Stor Ö (Large Island), seen by Dutch whalers in the seventeenth century.

In 1867, Rönnback circumnavigated West Spitsbergen and discovered a group of small islands on the western coast of Hinlopen Strait in 79° N.

In 1871, an English sportsman, B. Leigh Smith, chartered a Norwegian schooner under the command of Captain Ulve, an expert Norwegian ice navigator. Reaching the southern and later the northern coast of Northeast Land, they stated that this land stretched about 43 nautical miles farther eastward than was formerly believed.

In the following year knowledge of eastern Spitsbergen was advanced by Norwegian seal hunters. Taking advantage of an open season, Altman, Johnsen, and Nielsen reached King Karl Land and reported that there were several large and small islands divided into two groups by a large sound. Johnsen landed on the northeastern point of the eastern group.

In 1876 and 1887, eastward of the northeastern point of Northeast Land, two Norwegian walrus hunters, Kjeldsen and E. H. Johannesen, came in sight of an unknown island, White Island, the true Giles Land. In 1889, another Norwegian walrus hunter, Hemming Andreassen, completed our knowledge concerning King Karl Land by navigating the northern part of the sound dividing the two main islands, Svenska Förland (Swedish Foreland) and King Karl Island. This sound was called Rivalen Sound from the name of Andreassen's ship. According to Professor Nathorst, the sketch map of this Norwegian walrus hunter was not superseded until the survey of this group of islands was made by the Swedish expedition of 1898; it is, however, much more accurate than the map that Dr. W. Kükenthal, the well-known zoölogist of Jena, published after visiting King Karl Land in a Norwegian hunting sloop that same summer. So strong is respect for established authority in old Europe that in a new issue of their maps of Spitsbergen the British and French hydrographic offices reproduced the incorrect sketch made by the German scientist rather than the accurate one by the Norwegian skipper.

Finally, in 1898, Norwegian hunters, starting from the northeastern corner of Northeast Land, discovered beyond

THE WHARF AND CABLEWAY ON ADVENT BAY FOR UNLOADING COAL FROM THE MINE AT LONGYEAR CITY

White Island a new island, which they named Victoria Island. These seamen also reported that Spitsbergen and Franz Josef Land have a fringe of islands between them. These two polar lands form a dam which prevents the polar pack from flowing southward in great masses. To this circumstance northern Europe is indebted, in part, for its relatively mild climate.

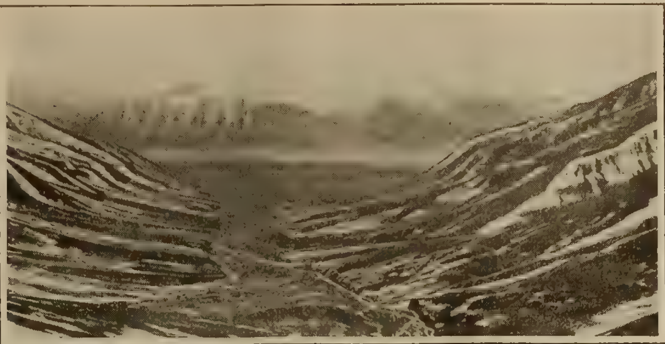
To summarize, we may say that in eastern Spitsbergen the Norwegian walrus hunters did admirable pioneer work, opening the way for further scientific expeditions. Also, geography is indebted to them for determining the directions of ice drift around Spitsbergen.

In order to complete the description of the contributions to our knowledge of Spitsbergen made by Norwegian hunters, it must be added that, of the trappers who have been winter-

[2]The survey of the Norwegian exploration of Spitsbergen here given summarizes a statement compiled by order of the Norwegian Government by Adolf Hoel, of the University of Christiania, the leading Norwegian explorer of these islands in recent years.

ing in the islands since the last years of the nineteenth century to catch bear and fox, eighteen parties made regular meteorological observations, both on the western and the eastern islands, with instruments lent by the Meteorological Institute of Christiania, and thus added substantially to our knowledge of the climatology of this Arctic land.

RECENT NORWEGIAN SCIENTIFIC EXPLORATION IN THE INTERIOR.



THE MALAR VALLEY LOOKING DOWN (SOUTHWEST) TO ITS JUNCTION WITH ADVENT VALLEY
(Photo by Engineer Koller, 1917.)

In 1906 the last chapter in the exploration of Spitsbergen was begun by Norwegian scientists, using new methods of exploration. Until then few expeditions had been undertaken in the interior, so that practically the whole inland portion of the islands remained a *terra incognita*. In 1906, the Prince of Monaco, having taken Spitsbergen waters as a field for oceanographical research, began the systematic survey of the western island. Establishing his headquarters in Cross Bay, he entrusted the mapping of the mountainous massifs stretching from that bay to Smeerenburg to Captain Gunnar Isachsen of the Norwegian army, who had been the topographer of Sverdrup's expedition to the American Arctic Archipelago. With a staff of Norwegian surveyors and naturalists and with Dr. Louet of the French army, Captain Isachsen admirably fulfilled his task in two summers.

The results are of great value.[3] About 200 square miles of Spitsbergen's ice world were mapped by accurate methods on the scale of 1:100,000 with contours of elevation. Never before had such a great area of the interior of Spitsbergen been surveyed, nor an Arctic land mapped so accurately. This successful expedition aroused in Norway a still greater interest in this region. The Norwegian parliament and private citizens granted large subsidies for pursuing the work initiated by Isachsen. Henceforward the foundations were laid for a systematic survey of the westen fiord region of West Spitsbergen and every summer thereafter one or two Norwegian expeditions went to the island.

In 1907 and 1910 a large expedition set off under the command of Captain Isachsen, numbering, besides the leader of the expedition, nine scientists. Extending in all directions the survey made on behalf of the Prince of Monaco, they brought back maps of northwestern Spitsbergen between the northern coast, Wijde Bay, and Ice Fiord, of the region adjoining Green Harbor in the last-named fiord, and of Prince Charles Foreland.[4] During the two summers in which the expedition was in the field more than 2,000 square miles were mapped, and a great quantity of geological data was gathered.

From 1911 to 1918, under the leadership of Adolf Hoel and Captains Arve Staxrud and Sverre Rövig, topographical and geological surveys were extended to the peninsula between Ice Fiord and Bell Sound and southward to the coastal region as far as Horn Sound. The work of the Norwegians in Spitsbergen from 1906 until 1918 may therefore be summarized as follows:

All the western coastal region as far as a point lying three statute miles south of Horn Sound is now accurately triangulated and mapped in detail.[5] That is a piece of land about 200 statute miles long and 18 to 58 miles wide, covering 5,600 square miles. For the northern sheets the scale of 1:200,000 has been adopted, and for the southern sheets 1:100,000 and 1:50,000. All these maps will soon be published; a chart of the western coast of Spitsbergen, more nearly correct and more complete than the British and German charts, has already been published by the Norwegian Hydrographic Office.[6] In the coming years the survey will be continued southward; it is hoped to reach South Cape by 1922.

These expeditions also attained geological results of exceptional value. The chief points of interest about these re-

[3]The scientific results of the expedition are laid down in the splendid series of monographs published by the Prince of Monaco under the title "Résultats des campagnes scientifiques accomplies sur son yacht par Albert Ier, Prince souverain de Monaco," Fascicules 40 (surveys; with the map, 1:100,000, showing relief and glaciers in contours and shading, 41 (glaciology), 42 (geology and physiography), 43 (geology), 44 (botany).

[4]The geographical results are contained in:

Gunnar Isachsen: Travaux topographiques de l'expédition Isachsen, 1909-1910, *Kristiania Videnskapsselskapets Skrifter: I. Mat.-naturv. Klasse,* 1915, No. 7 (=pp. 1-63). [Contains the map of northwestern Spitsbergen in 1:200,000, showing relief and glaciers in contours.]

Idem: Green Harbour, *Norske Geogr. Selskaps Aarbok,* 1912-13, pp. 151-162. [With a map of Green Harbor in 1:100,000.]

[5]Besides the Norwegian surveys there should be mentioned the map of Prince Charles Foreland, 1:140,000, by Dr. W. S. Bruce and M. J. Mathieson, published in 1913 by the Scottish Oceanographical Laboratory of Edinburgh with the support of the Prince of Monaco.

[6]Spitsbergen: Farvand og Ankerpladser paa Vest-og Nordkysten, 1:200,000, with seven insets, Norges Geografiske Opmaaling Chart No. 198, Christiania, first edition, 1912.

WINTER HUT OF NORWEGIAN TRAPPERS AT SAFE HARBOR, NORTHERN SHORE OF ICE FIORD
(Photo by Dr. Holtedahl, 1909.)

TRAVELING OVER THE ICE FIELD TOWARD THE THREE CROWNS, THE THREE SUMMITS SEEN AT THE LEFT
(Photo by Captain Gunnar Isachsen.)

GENERAL VIEW OF THE COAL MINE AT LONGYEAR CITY

The mine lies on the western side of a small tributary valley entering Advent Bay from the south. The entrance to the mine can be seen high up on the hillside to the left with a cableway leading from it down to the harbor on Advent Bay in the center of the view. The houses at the foot of the slope are Longyear City.

searches are the study of the Devonian on the northern shores, the discovery of Quaternary volcanoes and of hot springs on the western shore of Wood Bay,[7] and the true determination of the age of the massifs of crystalline schists in the northwestern corner. These schists, ascribed to Archean, belong to the upper Heckla Hoek series (Silurian).

Besides these systematic expeditions, there were several others equally successful.

In 1908, Mrs. Hanna Resvoll-Holmsen made a botanical survey of the fiord region in West Spitsbergen. The same year and again in 1912 her husband, Dr. Gunnar Holmsen, carefully studied the numerous strata of fossil ice[8] whose existence in the soil of Spitsbergen was discovered in 1892 by the author of this paper.

GLACIAL FEATURES OF WEST SPITSBERGEN.

Thanks to the Norwegian expeditions, the peculiar glacial phenomena of West Spitsbergen can now be outlined. In the northwestern corner there is no ice sheet. The former inland ice, which had totally covered the region, has shrunk, and now alpine crests rise above the ice to heights of 4,200 feet and delineate great ice streams. But eastward from a line joining Cross Bay with the head of Wood Bay the alpine crests merge into ice-covered plateaus. As reckoned by Isachsen, the glaciated area in the coastal region extending from Smeerenburg Bay and Liefde Bay to Cross Bay is 67 per cent of the total area. On the other hand, the great peninsula between Ice Fiord and Bell Sound with large plateau massifs divided by wide valleys bears no arctic character. In that part of Spitsbergen the glaciation is only local. The large valleys are bare in summer and have boggy soils and meager pastures. Forty years ago numerous herds of reindeer were to be found there in autumn. Southward from Bell Sound and around Horn Sound there is a rugged land with large coalescing glaciers issuing from an ice sheet occupying the interior back of the high coastal crests.

THE SURROUNDING SEAS.

The Norwegians have explored not only Spitsbergen, but also the surrounding seas. The first undertaking of this nature was the classic Norwegian deep-sea expedition headed by Mohn, Sars, and Danielssen which explored the Arctic Ocean from Iceland to Jan Mayen, Bear Island, and Spitsbergen (1876-1878). Later on, in 1900, Hjort and Nansen carried out a very valuable oceanographic cruise in the Arctic Ocean as far as Bear Island. In 1901, before starting on his Northwest Passage expedition, Roald Amundsen, on his celebrated *Gjöa*, investigated the oceanographic conditions around Spitsbergen.[9] During Isachsen's expedition in 1909 a great many vertical series of deep-sea observations were made.[10] Finally, in 1912, on his small yacht, Nansen investigated the waters of the western and northern coasts of Spitsbergen.[11]

The foregoing summary demonstrates the fundamental nature of the work the Norwegians have done in Spitsbergen. No other nation compares with them in their geographical discoveries, the number and accuracy of their surveys, and the extent of their scientific results in this archipelago.

INDUSTRIAL DEVELOPMENT—COLLIERIES.

With the twentieth century a new era begins in the history of Spitsbergen. Until then the archipelago had remained uninhabited, but during the past few years it has become a mining land and attracted a considerable number of Norwegian settlers. Coal deposits were long known to exist on the shores of Ice Fiord, but not until the first years of this century were they worked.

At present the best-developed collieries in Spitsbergen belong to Norwegian companies.

The Great Norwegian Spitsbergen Coal Company is working

[7]A. Hoel and O. Holtedahl: Les nappes de lave, les volcans et les sources thermales dans les environs da la baie Wood au Spitsberg, *Kristiania Videnskapsselskapets Skrifter: I. Mat.-naturv. Klasse*, 1911, No. 8 (=pp. 1-37). Adolf Hoel: Nouvelles observations sur le district volcanique du Spitsberg du nord, *ibid.*, 1914, No. 9 (=pp. 1.33).

[8]Gunnar Holmsen: Spitsbergens jordbundis og de bidrag dens undersokelse har kunnet gi til forstaaelsen av de i arktiske land optraedende varige isleier i jorden, *Norske Geogr. Selskaps Aarbok*, 1912-13, Christiania, pp. 1-132, with summary in German, pp. 133-150.

[9]Fridtjof Nansen: Northern Waters: Captain Roald Amundsen's Oceanographic Observations in the Arctic Seas in 1901, *Kristiania Videnskapsselskapets Skrifter: 1 Mat.-naturv. Klasse*, 1906 No. 3 (=pp. 1-145).

Björn Helland-Hansen and Fridtjof Nansen: The Norwegian Sea: Its Physical Oceanography Based upon the Norwegian Researches 1900-1904 (Reports on Norwegian Fishery and Marine Investigations, Christiania, 1909, vol. 2, No. 2). [A standard work.]

[10]Björn Helland-Hansen and Fridtjof Nansen: The Sea West of Spitsbergen: The Oceanographic Observations of the Isachsen Spitsbergen Expedition in 1910, *Kristiania Videnskapsselskapets Skrifter: I. Mat.-naturv. Klasse*, 1912, No. 12 (=pp. 1-89).

[11]Fridtjof Nansen: Spitsbergen Waters: Oceanographic Observations during the Cruise of the "Veslemöy" to Spitsbergen in 1912, *Kristiania Videnskapsselskapets Skrifter: I. Mat.-naturv. Klasse* 1915, No. 2 (=pp. 1-132).

the most productive coal seams on the island on the western side of Advent Bay, which it bought in 1915 fom the Arctic Coal Company of Boston, Mass.[12] From 1909 to 1915 the total exportation of coal by the Boston company amounted to 150,000 tons. In the three following years it amounted to 85,000 tons.[13] This year (1919) the Norwegian company was also to start the exploitation of another coal deposit at Green Harbor.

The Norwegian Kings Bay Coal Company is working on the south shore of Kings Bay.

There are in addition four other Norwegian coal companies now beginning development. One has bought the holdings of an English company on the northeastern side of Advent Bay and will resume work this year. The capital invested in the six Norwegian collieries amounts to $4,200,000.

After the Norwegians come the Swedish Spitsbergen Coal Company, working on both sides of Braganza Bay (Bell Sound), and a Russian company working between Green Harbor and Coles Bay under the management of a Norwegian engineer.

The British are far behind, with two companies: the Scottish Spitsbergen Syndicate, headed by Dr. W. S. Bruce, and the Northern Exploration Company. Several years ago Dr. Bruce did some mining work on coal seams on Prince Charles Foreland, but nothing further seems to have come of it. The Northern Exploration Company has quarried a conglomerate which was taken for marble on the north shore of Kings Bay. This stone is said to be of little value, and it is asserted that none has been exported. The same company also claims an iron-ore deposit in Recherche Bay (Bell Sound) which is emphatically proclaimed to be one of the richest of the world. Scandinavian geologists who have studied this deposit are not of the same opinion. The Northern Exploration Company has recently undertaken preparatory work for mining coal on an island in Bell Sound.

SETTLEMENTS AND POPULATION.

Advent Bay is the chief population center of Spitsbergen. On its western side lies Longyear City, the most important settlement of the archipelago, and now belonging to the Great Norwegian Spitsbergen Coal Company. It offers very good accommodations, comfortable houses, electric light—the last very necessary indeed during the four months of long polar night. There are also a telephone system, well-stocked stores, and a hospital attended by a physician. In the summer of 1918 Longyear City numbered 300 inhabitants, all Norwegians. On the opposite side of the bay there is another Norwegian settlement, Hiorthaven.[14] Its population, entirely Norwegian, does not exceed 100 souls in summer and 60 in winter.

Besides these there are, on the southern shores of Ice Fiord, two small Norwegian hamlets, one on land owned by the Russian company between Coles Bay and Green Harbor, and another in Ice Fiord, near the coal deposits belonging to the Great Norwegian Spitsbergen Coal Company. On the southern shore of Kings Bay a large Norwegian settlement has been built near the Norwegian colliery, and on an island of the same fiord are some houses belonging to the Northern Exploration Company. In Bell Sound, besides small Norwegian hamlets on both sides of the fiord, there are in Braganza Bay a Swedish village near the Swedish mine and a British settlement on Axel Island.

During the past summer the Norwegian population of Spitsbergen amounted to about 800 souls.

COMMERCE AND COMMUNICATIONS.

Among Spitsbergen shipping the Norwegian flag takes first rank:

Since Mr. Longyear sold his settlement to a Norwegian company, the other flags are represented only by a few units.

In 1917 the general commerce between Norway and Spitsbergen attained its highest figure up to that time, $1,240,000; in 1918 it was probably much higher, owing to the increase of coal exports.

At Green Harbor the Norwegian Department of Telegraphs has erected a powerful wireless station communicating with a station at Ingö, near the North Cape of Norway, and at the Norwegian settlements of Longyear City and of Kings Bay and at the Swedish settlement in Braganza Bay secondary wireless stations are installed. A Norwegian postal service is established between Norway and Spitsbergen, with three postoffices, at Longyear City, Green Harbor, and Kings Bay. In 1918, from June to October, postal steamers made 26 voyages.[15] At the wireless station at Green Harbor a complete meteorological station is working whose observations are published in the *Jahrbuch des Norwegischen Meteorologischen Instituts.*

BEAR ISLAND.

A Norwegian company has also occupied Bear Island (Beeren Eiland). Lying 108 nautical miles southwards from the South Cape of Spitsbergen, this island is not so cold as Spitsbergen. Its annual temperature is —4.3° C. instead of —9.7° C. at Green Harbor, but the East Spitsbergen polar current, flowing westward, carries extensive drift ice all around the island. When the season is good, Bear Island is entirely ice-free for at least four months; in bad years the sea remains ice-strewn until July, but navigation is possible before that time.

At Bear Island coal occurs in the Devonian and Culm strata. Since 1916 the building of a settlement and installations for the working of coal deposits have been under way; so far the exports have been small. Eighty men wintered this year on the spot.

PREDOMINANCE OF NORWEGIANS IN SPITSBERGEN NAVIGATION.

The Norwegians have also had the largest share in the industrial development of Spitsbergen. Besides this, their acquaintance with the ice conditions for more than a century has, in a way, given them the monopoly of navigation in this archipelago, and nearly all the expeditions that have visited this Arctic land have engaged Norwegians as ice masters, frequently even entirely Norwegian crews. Thus, if the Norwegian Government should forbid its nationals to pilot foreign ships to Spitsbergen, nearly all maritime traffic between these islands and other lands than Norway would cease or become very dangerous.

POLITICAL HISTORY.

Spitsbergen is not a "*terra nullius*," as it has been asserted. History establishes its rightful position.

At the end of the seventeenth century and for a long time aferwards Greenland was supposed to stretch northeastward and rejoin northern Russia by way of the Arctic Ocean. Barents himself and all his contemporaries were of the opinion that the land which he had discovered was part of a group of islands off the eastern coast of Greenland, and in this belief Spitsbergen was generally named Greenland until the beginning of the nineteenth century. Greenland belonging to the then united Norwegian and Danish crown, the King of Norway and Denmark accordingly claimed the ownership of Spitsbergen. This claim was also based on his generally accepted overlordship of the Arctic Ocean north and west of Europe, consequently of all the islands it contains wherever they might be and by whomsoever discovered.

In 1610 a number of whales in the western fiords of Spitsbergen having been seen by Jonas Poole, the news spread rapidly, and soon after numerous British, Dutch, French,

[12] Cf. *Geogr. Rev.*, vol. 7, 1919, p. 318.

[13] All the statistical data concerning the present economic status of Spitsbergen are taken from an official statement prepared by the Norwegian Government which will be issued several months hence.

[14] It takes the place of the former English mining settlement of Advent City, which no longer exists.

[15] During the fiscal year 1917-1918 the Green Harbor station received 2,041 telegrams and dispatched 3,323. It has intercepted 3,317 telegrams from other European and from American stations. In 1918, 10,322 letters, newspapers, and parcels were sent from Norway to Spitsbergen and 5,649 from Spitsbergen to Norway.

Danish, and Hanseatic whalers arrived at Spitsbergen. Among all these competitors troubles and disputes arose; even sea fights were not infrequent. The King of Norway and Denmark, Christian IV., protested against these incursions of his domain, and long diplomatic negotiations on the whale fishery and on the overlordship of Spitsbergen opened between the Norwegian-Danish monarch and the King of England, the States General of the Netherlands, the King of France, the Hanseatic cities, and the King of Sweden. These polar islands were the occasion of the first colonial conflict among European nations.

The King of England, James I, never expressly acknowledged the claim of Norway-Denmark regarding the sovereignty of Spitsbergen. Nevertheless in 1614 he offered to pay a rent to the Danish King, provided that English subjects should be granted a monopoly of the whale fishery in these islands together with the Norwegians and the Danes. Later on he suggested to Christian IV that he should sell him his right to "Greenland," that is Spitsbergen. The diplomatic transactions with England ended in 1621 by an agreement giving equal rights to English and Norwegian-Danish whalers in Spitsbergen. On the other hand, in 1632 the overlordship of the King of Norway and Denmark was accepted by the States General; however, a century later, in 1741, this acceptance was questioned by the Dutch. In 1663, 1679, and 1692, France, Sweden, and the Hanseatic cities respectively recognized the sovereignty of the King of Norway and Denmark over these polar lands.

Why has Spitsbergen today been declared *terra nullius?* During the second part of the seventeenth century, whales having deserted the coastal water of Spitsbergen, there was a cessation of the disputes regarding these islands. When two centuries later, in 1872, Spitsbergen again found a place in the minds of diplomats, the old transactions were totally forgotten, and the archipelago was proclaimed *terra nullius.* Only recently, in 1912, Dr. Arnold Raestad revived a knowledge of their history, basing his information on the state papers of Great Britain, Denmark, the Netherlands, and France.[16] Is there no such thing in regard to treaties as title by long possession? By inheritance of the Danish king's rights Norway possesses the sovereignty of the archipelago, but this sovereignty is not complete, not having been recognized by all the powers.

[16]Arnold Raestad: Le Spitsberg dans l'histoire diplomatique (translated from the Norwegian by Charles Rabot). *La Géographie,* vol. 25, 1912, pp. 335-354; vol. 26, 1912, pp. 65-98. The Norwegian original, "Norges hoihetsret over Spitsbergen i aeldre tid," Christiania, 1912, contains 47 original documents.

Higher Steam Pressures*

What Its Adoption Will Mean

IN theory it has long been established that there is everything to gain by the adoption of relatively high steam pressures, and practically nothing to lose. As long ago as 1896 Prof. R. H. Thurston made this abundantly clear in his paper on the "Promise and Potency of High-Pressure Steam." And since that time the science of thermo-dynamics having been more widely recognized by engineers as a sure guide to improvement of heat engine economy, the tendency to increase the temperature range of the working fluid has been more than ordinarily active.

But of these figures we have at the moment little concern; they merely lead the way to more practical considerations. They take us quite naturally up to that point where we begin to consider the ultimate possibilities involved in the adoption of much higher steam pressures. And here must we divide into two separate and distinct phases of treatment our lines of thought; for we shall have to consider (*a*) what the adoption of higher steam pressures would mean in the design and construction of boiler machinery, and (*b*) what it will mean in the design of those parts outside the boiler, and which are to be subjected to the proposed higher pressures and higher temperatures.

An Example of Present-Day Practice.—In the best present day practice, except for slightly higher pressures in some few isolated cases, the maximum steam pressure is 200 lb. per sq. in. absolute, the super-heat 200° Fahr. The corresponding temperature of evaporation is therefore 382° Fahr., the bulk of the heat being absorbed at a temperature 20° Fahr. below the maximum. An outside instance of the practical adoption of a considerably higher steam pressure than this is supplied by the 1,500 kw. turbine installation recently constructed by the British Thomson-Houston Co., in which a steam pressure of 350 lb. per sq. in. was employed together with a superheat of 700° Fahr., exhausting into a condenser of 28½ in. vacuum. As clearly illustrating the measure of economy obtained as a result of such increase of pressure and superheat, it was claimed that during a 10-hour full load test only 1.83 lb. of coal per unit generated was consumed.

This, perhaps, might well be considered a notable achievement in a twofold sense, inasmuch as such increase of pressure was accompanied with an almost unprecedented increase in temperature of the working fluid. Certainly it stood as an exemplification of far higher temperatures than had hitherto been employed outside experimental phases. But we will deal with this aspect of the case at a later stage.

Effect on Standard Boiler Design.—Assuming the employment of higher steam pressures to be justified what effect will this have upon standard boiler design? Present-day boiler designs and specifications do not permit the generation of steam at a pressure higher than 200-250 lb. per sq. in. without sacrificing safety, and without calling for an investment in the boiler plant high enough to offset the gain in economy caused by higher steam pressures.

Must all existing examples of boiler design be scrapped? Must all drums and steam vessels of large diameter, flat surfaces and even dished ends be abandoned—yes, even if stayed? Will all riveted, expanded or beaded joints exposed to the action of the fire have to go by the board? Will nothing but electrically welded joints permit such an increase as contemplated? Will the high-pressure generator of the future be cylindrical? Of the water-tube type? Or of the flash type? Is increased efficiency to be effected primarily along lines altogether different from those obtaining in boilers working under pressures used today? Or is it possible to retain present-day design and to increase the evaporation per sq. ft. of heating surface twice as high as that represented by the present-day practice?

These are questions involving much thought, demanding perhaps new and original channels of investigation, pregnant with possibilities. Who knows? Perhaps, after all, our best brains in the realms of engineering science, our efforts, our striving after heating efficiencies have been utterly misdirected, in that they have been conducted along altogether wrong channels. When an apparent limit has been reached in one particular direction often it is that a striking off at a tangent into the seemingly impossible will result in undreamed of achievement.

In view of the considerably higher temperatures involved in the production of these high steam pressures we have in

*Reprinted from *The Electrician* (London).

mind, and supposing the waste gases leave the boiler at a temperature of 700°-800° Fahr., will it not be necessary to conserve as large a proportion as possible of the heat units if efficiency is also an end in view? This will bring us to a new consideration of the functions and limitations of the economizer. Or might it be suggested tentatively that the waste gases, or at least a portion of them, might very profitably be used in a regenerative form to heat the air which supports combustion in the furnace?

Effect on Materials.—Passing from the boiler itself to outside constructional parts in the event of higher steam pressures being generally adopted, we find less insuperable difficulties barring the way. Pressures of from 600 to 800 lb. per sq. in. are not uncommonly met with today in internal combustion engine practice, as evidenced by the Diesel engine; higher even than these in compressed air and hydraulic installations. But it will not be pressure alone that will have to be taken into account in the matter of future design innovations; an increased superheat will mean infinitely more than any contemplated pressure increase. If we add 600° or 700° of superheat it is quite true that we shall effect a considerable saving, notably in pipe lines, seeing that higher velocities would be used, and that superheated steam has a much lower thermal conductivity than saturated steam. But what of the boiler fittings and valves, the blading at the high pressure end of impulse turbines? In the latter connection the proposed increase of pressure might well be compensated for by increasing the thickness of the walls, by substituting steel for cast iron, but very much higher temperatures will necessitate the adoption of a special heat-resisting steel alloy for the blades at the high-pressure end of the turbines. Or it may well be that much of the difficulty in this direction will be got over by the employment of cross compound types of turbine, such as are employed in marine work, each turbine driving a separate generator, the change of temperature in each unit being thus considerably reduced.

High Pressure and Reciprocating Engines.—With such increase both of temperature and pressure, reciprocating engines of the double flow type must, because of their excessive condensation losses at the period of steam admission, and to heat transference between the steam and the cylinder walls, give place to the uniflow type of piston engine. But as against the adoption of the latter must be set the fact that it is impossible to carry expansion down to the condenser pressure; this is a factor that will need thoughtful consideration. But might it not be got over by operating it as a non-condensing engine, utilizing the heat from the exhaust in the feed water?

It is a debatable point whether the future will see cast iron holding its present position in the constructional details of steam engines. Many cases can be cited of casting failures where the final temperatures of the steam was only 500° Fahr., while on the other hand there are doubtless many plants using superheated steam of a temperature even higher than this, equipped with nothing but cast iron fittings and valves.

Some authorities hold that providing the cast iron contains a large proportion of steel in order to give it the necessary strength to resist the greater expansion strains involved, and is low in silicon content, there is little need for the employment of cast steel in the event of any reasonable high temperatures being adopted. But doubtless this assumption would have been based on present-day practice, and would not therefore hold good for the very much higher temperatures now in contemplation.

In piston engines of the double-acting type the question of cylinder lubrication will be all important in the event of higher steam pressures and increased superheat. It is questionable if the advent of pressures of from 400 lb. to 600 lb. per sq. in., together with a superheat of from 500° to 800° Fahr. will permit of the use of either slide or Corliss valves. The packed rod might also present insuperable difficulties. This then would lead us inevitably to the consideration of the single-acting type of engine; perhaps from the point of view of weight per horse-power and efficiency, the only logical design for these higher pressures.

Also important in piston engines is the question of cylinder lubrication. The greater proportion of the lubricating oil now used in piston engines is required for the steam distributing valves; that actually required by the piston and piston rings being comparatively small. Consequently, the possibility of sufficient piston lubrication is not affected by higher initial steam pressures, because even in case of very high mean effective pressures in single-acting engines, where the piston serves as crosshead, and therefore requires constant lubrication, the piston can be made sufficienty long to keep the pressure per square inch within safe limits.

It thus seems clear that if we increase steam pressures to say 500 lb., or 600 lb., per sq. in. without using temperatures much higher than those employed in modern practice, the more radical changes in design will be those requiring to be effected in the steam generator. But if we increase in the same proportion the existing degree of superheat—and this seems almost essential if the fullest advantages are to be obtained—then must the changes in design be much more comprehensive; and will exercise to the utmost the skill and judgment of engineers and power plant designers.

EFFECT OF DECAY ON WOOD PULP.

Clean groundwood pulp and pulp infected with molds and fungi have been used in recent comparative paper-making trials at the Forest Products Laboratory. These trials showed that infected pulp was inferior to clean pulp in the following respects:

The infected pulp produced a very dirty sheet. It required more sizing than the clean pulp. It stuck to the couch and press rolls and gave trouble from excessive foaming.

Although groundwood pulp is usually considered too slow, the extreme freeness of the infected pulp caused difficulty in carrying the necessary amount of water on the paper machine to secure a good formation in the finished paper.

Based on the percentage of groundwood, the infected pulp used in the experiments yielded 10 per cent less finished paper than the clean pulp.

The strength of the finished paper was greatly reduced by the use of infected pulp. In a groundwood sulphite finish, this decrease in strength would necessitate the use of a larger percentage of the more expensive sulphite pulp.

KILN DRYING OF GREEN HARDWOODS.

Successful kiln drying of hardwood lumber green from the saw necessitates a very even control throughout the kiln at all times. This means that variations in temperature of even a few degrees or variations in relative humidity of 5 to 10 per cent are seldom permissible. Such uniformity is possible only when the heating coil is properly drained, is relieved of air, and is distributing heat uniformly along its length.

It is the contention of the Forest Products Laboratory that the return-bend heating coil system, by bringing about more uniform distribution of heat in the kiln, enables the operator to obtain quicker and better drying than is possible with the header-coil system, as it is generally installed.

The return-bend heating coil gives a practically even heat distribution under any steam pressure. The header-coil produces different temperatures at either end of kiln, the extent of variation depending on the steam pressure, length of coils, drainage, traps, etc.

Refractory hardwoods require low temperatures, and the lower the temperatures used, the more evident will be the difference in the results obtained with these two types of heating equipment. Under the same careful operation, green hardwood lumber may be turned out from kilns using the one type satisfactorily dried, and from kilns using the other type checked and overdried at one end and molded and underdried at the other end.

Firing Steam Boilers Without Flame*

Recent Developments in Surface Combustion Boilers

By Professor William A. Bone, D.Sc., F.R.S., and P. St. G. Kirke, M.A., A.M.I.C.E.

WHAT is now known as the Bonecourt system of surface combustion embodies the practical results of certain discoveries made by one of us during scientific researches upon the influence of hot surfaces in promoting gaseous combustion. It is recognized nowadays by all chemists that chemical interactions in gaseous systems are promoted by the catalytic action of hot surfaces, and the case of gaseous combustion is no exception to this general law. The researches referred to proved that, if an explosive gaseous mixture be either injected on to or forced through the interstices of a porous refractory incandescent solid, under certain conditions, a greatly accelerated combustion takes place within the interstices or pores: or, in other words, within the boundary layers between the gaseous and solid phases wherever these may be in contact and that the heat developed by this intensified combustion would maintain the surface in a state of incandescence without any development of flame, thus realizing the conception of flameless incandescent surface combustion, as a means of greatly increasing the general efficiency of heating operations wherever it can be conveniently applied.

Perhaps the simplest illustration of this system of flameless incandescent surface combustion is afforded by the diaphragm method of applying radiant heat, and it was obvious from the first that important results would accrue if by any means it could be successfully applied to the raising of steam in gas-fired boilers.

It will probably be generally admitted that up to a few years ago the gas firing of steam boilers had not been very successful from the point of view either of thermal efficiency or rate of evaporation. The low thermal efficiency of boilers fired in the ordinary way by blast furnace gas is notorious, while even in the case of boilers fired with coke oven gas the thermal efficiency probably did not much exceed 65% or 70%.

The first experiments made in the year 1909 by the late Mr. C. D. McCourt and one of us upon the application of the principle of surface combustion to the gas firing of multitubular boilers, proved the possibility of transmitting between 90% and 95% of the net calorific value of coke oven gas to the water in the boiler. The nature of these early experiments has already been dealt with so often in public that it will be unnecessary for us to enlarge very much upon them. Suffice it to say that the first experiment in Leeds was made with a single steel tube 3 ft. in length and 3 in. in diameter, packed with fragments of granular refractory material, meshed to a proper size, and fitted at one end with a fireclay plug through which was bored a circular hole ¾ in. diameter, for the admission of the explosive mixture of gas and air at a speed greater than that of back-firing.

Experimenting with such a tube, it was found possible to burn completely a mixture of 100 cub. ft. of coal gas plus 550 cub. ft. of air per hour, and to evaporate about 100 lb. of water from and at 100° C. (212° F.) per hour (20—22 lb. per sq. ft. of heating surface), the products leaving the further end of the tube at practically 200° C. This meant the transmission to the water of 88% of the net heat developed by the combustion, and an evaporation per sq. ft. of heating surface nearly twice that of an express locomotive boiler. The combustion of the gas was completed within 4 or 5 in. of the point where it entered the tube. Of the total evaporation, no less than 70% occurred over the first linear foot of the tube, 22% over the second foot, and only 8% over the last foot. This pointed to a very effective "radiation" transmission from the incandescent granular material in the first third of the tube, where the one of active combustion was located, although it should be remarked that the loci of actual contact between the incandescent material and the walls of the tube were so rapidly cooled by the transmission of heat to the water on the other side that they never attained a temperature even approaching red heat. The granular material in the remaining two-thirds of the tube served to baffle the hot products of combustion and to make them repeatedly impinge with high velocity against the walls of the tube, thus materially accelerating their cooling, and either preventing or minimizing the formation of the feebly-conducting stationary film of relatively cold gases which in ordinary practice clings to the tube walls, seriously impairing the heat transmission.

From this initial experiment Bone and McCourt proceeded to construct their first experimental boiler (Fig. 1) which was made of ten such tubes fixed horizontally in a cylindrical steel shell capable of withstanding a pressure of over 200 lb. to the sq. in. This small boiler was connected with a small tubular feed water heater containing 9 tubes, each 1 ft. long and 3 in. diameter, similarly packed with granular material to facilitate the exchange of heat.

With this simple combination of boiler and feed water heater we were able to transmit to the water 93.3% of the net heat units contained in London coal gas of 510 B.T.U. net per cub. ft. at N.T.P. and obtain an average rate of evaporation of as much as 33.9 lb. water per sq. ft. of heating surface per hour (from and at 212° F.); the steam gage pressure was 103 lb. and the products of combustion left the feed water heater at a temperature of 289° F.

The details of these results are shown in Table 1.

TABLE 1.

	8 Dec. 1910.	8 Jan. 1913.
Net cal. value gas in B.Th.U. per cub. ft. at N.T.P.	562	510
Rate of evaporation lb. water per sq. ft. heating surface per hour from and at 212° F	21·6	33·9
Pressure of gaseous mixture entering the tubes. Ins. W.G.... ...	17·3	40·9
Pressure of products entering the feed water heater. Ins. W.G. ...	2·0	5·14
Steam gauge pressure in lb. above atmospheric	100	103
Boiling point water in Fahr.° ...	338°	340°
Temperature products leaving boiler in Fahr.°	446°	534°
Temperature products leaving feed water heater Fahr.°	203°	289°
Net heat supplied to boiler per hour in B.Th.U.	559,800	728,333
Net heat transmitted per hour in B.Th.U.	527,800	680,000
Efficiency ratio	0·943	0·938

SKINNINGROVE BOILER FOR COKE OVEN GAS.

The success of this first experimental boiler enabled us to proceed immediately with the erection of a much larger plant (Fig. 2) on similar lines for coke oven gas, at the Skinningrove Iron Works in the year 1911. It consisted of a boiler drum 10 ft. in diameter and 4 ft. from front to back, traversed by 110 steel tubes each of 3 in. internal diameter, packed with fragments of suitable refractory granular material. To the front of the boiler was attached a specially designed gas feeding chamber which delivered washed coke oven gas at the ordinary temperature and under a pressure of 1 to 2 in. water gage to each of the 110 combustion tubes. This gas, together with a regulated proportion of air from the outside atmosphere, was drawn under suction from a fan,

*From the *Journal of Soc. of Chem. Ind.*

through a short mixing tube, into each of the said combustion tubes where it was burnt without flame in contact with the incandescent granular material. After leaving the boiler tubes the products of combustion passed onwards into a semicircular chamber at the back of the boiler, into a tubular feed water heater and from thence they were drawn by the fan which discharged them at a temperature of 95° C. into the atmosphere.

In a series of independent trials carried out on the plant by an eminent American steam engineer in July, 1912, it was found that, even when the boiler was not lagged and when it was raising steam at a pressure of 100 lb. above that of the atmosphere, 92.7% of the net heating value of the coke oven gas was transferred to the water and sent out as steam, the overall evaporation being at the rate of 14 lb. per sq. ft. of heating surface per hour (see Table 2).

TABLE 2.

Results of Steam Trial.

July 29th, 1912.

Duration of test in hours	10
Mean steam gas pressure in lb. per sq. in. above atmospheric	97·2
Total gas burnt in cubic ft. at N.T.P.	101,853
Net calorific value of gas B.Th.U. per cub. ft. at N.T.P.	510·5
Total *net* heat supplied. B.Th.U. ...	52,003,996
Temperature of products leaving boiler in Fahr.°	386(196° C.)
Temperature of products leaving feed water heater in Fahr.°	202(94·6° C.)
Total water evaporated in lb. from and at 212° F.	49,824
Evaporation in lb. per sq. ft. of heating surface per hour	14·1
% of dryness of steam	99·3
Total heat utilised in B.Th.U.	48,208,399

$$\text{Ratio } \frac{\text{heat utilised}}{\text{net heat supplied}} = 0{\cdot}927$$

$$\left.\begin{array}{l}\text{Power taken by fan}\\ \text{[suction=20'' W.G.]}\end{array}\right\} = 6097 \text{ watts} = \text{(say) } 8{\cdot}2 \text{ h.p.}$$

As is often the case, the first attempt to translate a new idea of this kind into everyday large-scale practice was not unattended with difficulties, the investigation of which has taught us certain valuable lessons. There was no difficulty whatever with the Skinningrove boiler or boiler tubes, or with the gas feeding arrangements. Notwithstanding the high evaporation, the mechanical properties of the tubes were not

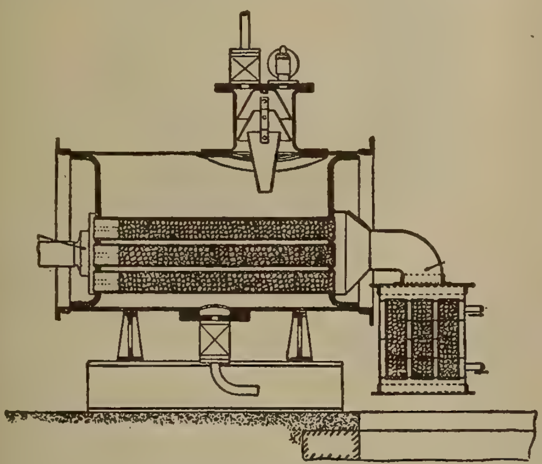


FIG. 1. FIRST EXPERIMENTAL BOILER

in the least impaired, and the Skinningrove experiences have shown that there is nothing wrong with the evaporating part of the installation. On the other hand the type of fan put down at first to draw the gases through the system and to discharge the cool products of combustion into the atmosphere was found to be unsuitable for dealing with corrosive gases containing small quantities of oxides of sulphur at the extremely low temperature of 95° C., to which the products were reduced by the feed water heater. The burnt products had no corrosive action at all upon the boiler tubes or tube plates, but they were found to attack the outlet tube plate of the feed water heaters and the fan impellers.

The average temperature of the products leaving the boiler when evaporating at a gage pressure of 95 lb. to the sq. in. was about 195° C., or only 28° C. above the temperature of the steam. The effect of the feed water heater first installed was to reduce this temperature to practically 95° C., which was too low to prevent corrosive action. According to our experience, 120° C. is the lowest limit to which the temperature can be reduced without the risk of corrosive action upon the fan, and to allow a sufficient margin of safety at light loads it would be preferable not to reduce it below 130° C.

As there was no superheater, the work which could be done by the feed water heaters in reducing the products from 195° C. to 130° C. was so small that it was decided, in altering the Skinningrove plant, to cut out the feed water heater altogether and to substitute fans running at a lower speed, and fitted with water-cooled oil ring lubricated bearings on account of the higher temperature of the products to be dealt with, and this has been done. The efficiency of the plant, now that the boilers are lagged, will still be about 90% on

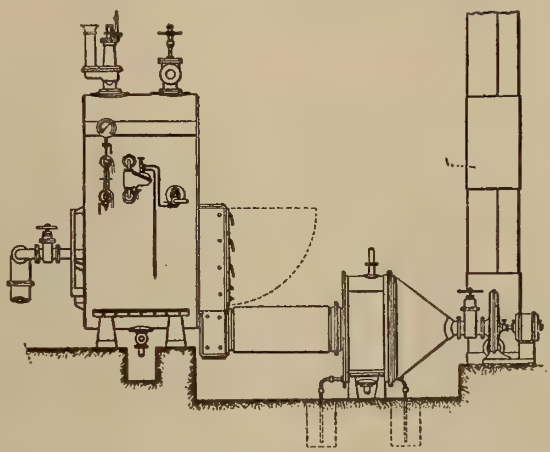


FIG. 2. LARGER PLANT AT SKINNINGROVE IRON WORKS

the net calorific value of the gas supplied, even without the feed water heater.

BOILERS WITH RIGID BLOCK PACKING FOR PRODUCER GAS.

Several other boilers of the Skinningrove type, with certain modifications in the packing and burners, and reduced suction, have been installed by the Bonecourt Waste Heat Boiler Co., Ltd., London, on the mains of the South Metropolitan Gas Company and the Gas Light and Coke Company. From a technical point of view we are still prepared to erect large boilers of the modified Skinningrove design for coke oven or coal gas, and to guarantee their high thermal efficiency and smooth working, but as the result of more recent developments in regard to the structural features of the boiler, we would now recommend one or other of the types to be described presently, which have been duly protected by patent applications.

Although a boiler with 100 or more tubes, each 4 ft. long by 3 in. diameter, packed with loose fragments of a suitable granular refractory material, as in the case of the Skinningrove boiler, is eminently suitable for use with a perfectly dustless and tarless gas, such as coke oven gas, it is preferable, when dealing with gases which are liable to contain dust or tar, to substitute a special rigid system of refractory surfaces (Fig. 3) over which the combustible mixture sweeps and in contact with which it is burnt at a highly accelerated rate. This has enabled tubes of much greater length to be used, which has the advantage of reducing the diameter of the boiler, reducing the number of burners, and reducing the cost of construction for a given evaporation. A further ad-

vantage is that the amount of suction required has also been considerably reduced.

The use of this new rigid system of refractory packing has also reduced the maximum temperature produced on the packing surfaces in the front part of the boiler to a degree certainly below 1,000° C., and probably to about 850° C. This has been done by facilitating the heat transmission to the water by free radiation from the whole of the packing surfaces to the tube walls. As an illustration of these newer types of boilers we may describe the constructional features of two boilers erected in the year 1914 in the Birmingham district for generating steam from gas made in Kerperley producers.

These boilers are each 10 ft. diameter by 12 ft. long; each unit contains 38 tubes, 6 in. diameter, packed with the special rigid system of molded refractory blocks. Each of the tubes is provided with its own gas supply, which can be easily regulated by means of a wheel-valve on the boiler front, while the air requisite for combustion, together with a regulated proportion of gas, is drawn into each tube, through a short mixing chamber, by the suction of an electrically driven fan situated at the back of the installation. Each unit will evaporate up to 15,000 lb. of water from and at 100° C. per hour. The combustion in the tubes is perfect, and when operating at a gage pressure of 85 lb. per sq. in. the products leave the system (there being no feed water heater included in the installation) at less than 250° C.

FIG. 3. RIGID SYSTEM OF REFRACTORY SURFACES

These two boilers, it may be said, have been running continuously for nearly five years, and no tubes have yet had to be renewed in them.

The only criticism which we have to pass as the result of experience gained in working them, and which led us to adopt further modifications, is that we did not consider that a burner system which involved the use of separate wheel valves for each tube of the boiler could be regarded as finality, and that it would be an advantage, from the point of view of evaporative power, if by any means tubes of smaller diameter and still greater length could be adopted in order to increase the heating surface.

The next step was an important improvement in the design of the burner which has enabled us to dispense entirely with separate control for each boiler tube and to feed a whole nest of tubes from a gas-box controlled by one valve. The elements of this design are shown in Fig. 4. The illustration of this newest burner shows a gas chamber controlled by one valve capable of supplying gas to a nest of 26 boiler tubes. The gas is fed into chamber from a main on which there is a cock controlling the pressure in the gas-box. The front of the box is bored with a number of holes, of the correct size, each of which is immediately opposite the axis of one of the boiler tubes. These holes are of uniform bore, but their diameters are adjusted by a rimer in such a way that with a given gas pressure in the box each delivers exactly the correct quantity of gas to each boiler tube even when that quantity may vary slightly in different tubes. Hence the quantity of gas admitted to each tube depends simply upon the pressure in the box which is controlled by the single valve referred to. While the quantity of gas is controlled by the gas pressure, the air is controlled by the fan, and all the operator has to know is how to vary the two together for different loads, which information is given him by the company's expert when the boiler is first put into commission.

BOILERS WITH SPIRAL PACKING.

In one small boiler operating on London coal gas with natural draught fitted with such a feeding chamber there are 26 tubes, each 2 in. diameter, and 4 ft. long. Each tube is fitted with an iron packing of spiral form, the front part of which becomes red-hot and acts as the catalyzing surface for the combustible mixture, and so completes the combustion flamelessly in the first foot of the boiler tube. The products of combustion sweep through the system in a spiral motion and rapidly give up their sensible heat to the water.

EXPERIMENTS UPON SUPERHEAT.

During the early stages of the development of our designs we were concerned mainly with the problem of evaporation and heat transmission. The important subsidiary problem of superheat was left until later. It was of course recognized that it would be impossible to develop the system for large power station work where high superheats are required unless a satisfactory solution of the subsidiary problem had been arrived at. During the war the problem was tackled on an experimental scale, with results which have enabled the boiler design to be modified so as to provide for superheats up to the highest degree required in modern power station practice. As these experiments were begun at a time when we were using tubes of 6 in. diameter, the well-known and well-tried locomotive type of superheater adapted for insertion in flue tubes of 5½ in. diameter or thereabouts was first tried.

In the first experimental arrangement a tube 13 ft. long and 6 in. diameter was packed for the first 4 ft. of its length with the aforesaid rigid block packing, for the next 6 ft. with a superheater element, and for the remaining 3 ft. with a specially shaped packing. The tube was fitted into a boiler shell 18 in. diameter suitable for a working pressure of 100 lb. to the sq. in. The gaseous mixture was burnt and the temperature of the products reduced to 1,300° F. (about 700° C.) before reaching the superheater element, and, after leaving the latter, the sensible heat remaining in the products was rapidly given up to the water in the boiler. By means of this arrangement steam at 100 lb. pressure was superheated

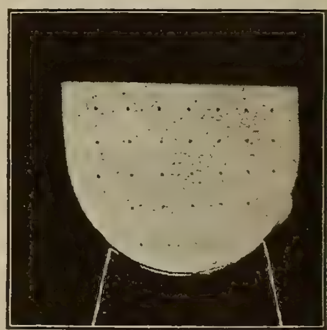


FIG. 4. GAS CHAMBER SUPPLYING 26 BOILER TUBES

192° F. to a total temperature of 530° F., while at the same time the temperature of the products leaving the system was reduced to 442° F., which was only 104° F. (58° C.) above the temperature of the saturated steam in the boiler. No feed water heater was attached in this experiment. In another experiment a superheat of 340° F. was obtained; the total temperature being 678° F., but in this case the temperature of the products leaving the system rose to 500° F., or 162° F. (90° C.) above that of the saturated steam in the boiler.

The improvements already described in the burners of the boilers, and the return to tubes of smaller diameter made it advisable to discard the locomotive-type of superheater in favor of a modified type of that commonly used in Lancashire boilers.

Finally a complete unit, as shown in Fig. 5, comprising the boiler, burners, superheater, feed water heater and fan, all on one foundation, has been designed. The boiler itself is 6

ft. diameter by 18 ft. long. There are two nests of tubes which are packed with the iron spiral packing already referred to. Each nest is fired from one burner-box and controlled by one valve. The packing of the tubes is so arranged that the products of combustion will pass from the boiler to the superheater at a temperature of 500° C., more or less according to the amount of superheat required, while the sensible heat contained in the gases leaving the superheater is recovered in the feed water heater, the temperature of the gases being reduced to 130° C. in the feed water heater, at which temperature they enter the fan. Such a combined arrangement of boiler superheater, and feed water heater in one unit has the advantage that it allows of a greatly increased evaporation in the boiler itself per unit of heating surface as compared with the former arrangement of boiler only, and, so far as can be estimated from our experiments, this small boiler would easily evaporate 20,000 lb. water from and at 212° F. per hour when supplied with coke oven gas, and 15,000 lb. from

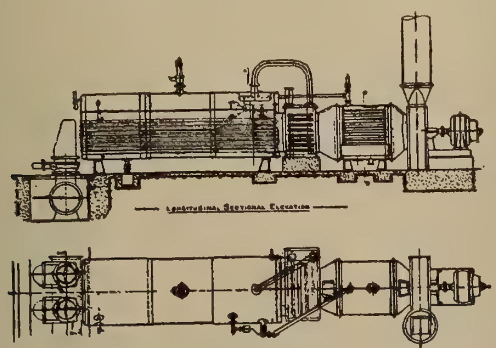


FIG. 5. COMBINED ARRANGEMENT OF BOILER SUPERHEATER AND FEED WATER HEATER IN A SINGLE UNIT

and at 212° F. per hour when supplied with producer gas. In either case the suction would not be more than 9 in. of water, and the overall thermal efficiency would be the same as in the original Skinningrove unit.

As the pressure at which steam is generated in modern central power stations is rapidly increasing it is interesting to note that the boiler shown in Fig. 5 can be made out of ordinary plate for a working pressure of 450 lb. to the sq. in.

Objections sometimes put forward against shell boilers are not applicable to the Bonecourt boiler as, like the shells used in water-tube boilers, they are neither subjected to contact with the hot gases, nor used as part of the heating surface. Moreover, unlike some water-tube boilers, the shell plates are not drilled to accommodate tubes. They have the great advantage over water-tube boilers in that there is no internal pressure tending to burst the tubes. The tubes are floated by the water, and as the water can flow to the heating surface over the whole length of the tubes instead of only at one end, the boilers can be forced in an extraordinary manner without risk of priming or of burning the tubes out.

In water-tube boilers it is common practice to couple a number of shells in parallel. In the Bonecourt boiler, not only can drums be placed side by side, but also one above the other and yet controlled by a single set of steam fittings. From these remarks it will be seen how easy it is to make a Bonecourt multi-drum boiler for almost any output and for any desired pressure and superheat, the space occupied being far less than that of any other boiler. Back-firing is impossible, and there are no large combustion chambers in which dangerous explosions can occur.

WASTE HEAT BOILER DEVELOPMENT.

In addition to the development of surface combustion boilers described in this paper, considerable progress has been made commercially with the installation of waste heat boilers in various parts of the kingdom, for the generation of steam from the hot products of combustion discharged from internal combustion engines and industrial furnaces.

"BLUE-SHORTNESS" AND AGEING OF IRON.

H. FETTWEIS attempts in *Stahl u. Eisen* a comprehensive explanation of "blue-shortness" and the ageing of iron and steel, based on the following theory:

By working the material at temperatures below 500 deg. C. a transformation is set up, which may be termed "ageing." This "ageing," which tends to intensify the effect of cold-working, requires months and years to develop at ordinary temperatures, but takes place more quickly with a rise in temperature, so that it may even develop in fractions of a second and so cause the phenomena of blue-shortness. From about 100 deg. C. onwards the consequences of ageing are weakened by the effects of reheating or tempering the metal, which effects are more pronounced the higher the temperature.

Based on this theory, it is possible to throw light on the following phenomena:

(1) In strength tests carried out on that material, a minimum value of the tensile strength is found at 80° C., and a maximum between 200° and 300° C., in the case of tensile tests carried out at ordinary speed. When the speed of test is increased, the curve showing the strength in terms of temperature is displaced in the direction of the higher temperatures. The yield-point gradually falls with increasing temperature. The resistance of iron to repeated impacts also shows value between 200° and 300° C. whereas the minimum notch-impact strength as determined by a single blow lies between 400° and 500° C.

(2) If iron is worked at temperatures below 500° C., and afterwards tested at room temperature when cold, a maximum and minimum respectively for all the strength properties of the material is found between 200° and 300° C. The tensile strength minimum at 80° C. disappears.

(3) The same results as in (2) are attained when the material is worked cold and then heated to a higher temperature for not too long a time.

(4) In order to bring about the above-mentioned changes in iron, which are characteristic of "blue-shortness," it is not necessary to heat it, but it is sufficient to have the cold-worked material lying at ordinary temperatures for some time, *i. e.*, to allow it to "age."

(5) If completely aged iron is reheated to different temperatures, then on afterwards testing the material it is found that all the strength properties gradually fall or rise with increase in the reheating temperature, without, however, showing a maximum or minimum value.

STEAMSHIP SUNK BY SUBMARINES TO EXTINGUISH A FIRE.

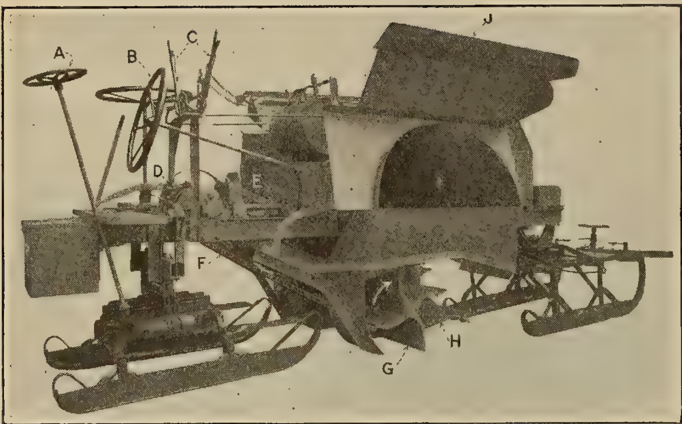
THE most spectacular and costly marine accident which has occurred at the Panama Canal since it has been in operation, resulted from an explosion in the hold of the American steamship "Marne" on the afternoon of January 24, while she was reloading part of her cargo at pier 11, Cristobal. The explosion was immediately followed by fire. In the cargo was 160,000 cases gasoline and benzine and in her tanks about 1,700 tons of fuel oil. The fire of this inflammable material being beyond the control of the terminal fire engines and fire tugs, the ship was towed away from the pier and sunk in shallow water. The great heat made it impossible to sink the vessel by opening cocks below the water line and she was sunk by shots from two of the Navy submarines. Fifty-four shots were fired from 3-inch guns. Armor-piercing shells were used first, fired into the vessel amidships. The holes they made were not large enough to admit water rapidly, and about six shrapnel shells were fired into the stern which pierced the hull and the "Marne" settled and sank in about 40 feet of water, inside the breakwater, about a mile from the outer end. After sinking, her decks were awash and the oil floating on the top continued to burn. Cases of gasoline and benzine on fire floated away from the ship and spread out over the harbor for a distance of half a mile. At night, these were a lurid and unusual sight.—From *The Panama Canal Record.*

Clearing Canadian City Streets of Snow*

Horse-drawn, Power-operated Snowplow

A POWER-OPERATED rotary snowplow hauled by horses is a new development in machinery equipment for cities where removal of snow is a serious and annual problem. Such a machine is being used on streets, suburban roads and sidewalks in some Canadian cities with satisfactory results as to both efficiency and economy. The general design is shown in Fig. 1, while our frontispiece shows a rear view of the machine in use. In Fig. 2 the plow is shown working on a sidewalk in a residential district. Its weight is about three tons and its length is 18 ft. over all.

Swiveling sleds carry a steel frame 14½ feet long, the team being hitched to the forward sled and the rear sled being steered by means of a handwheel. Upon the frame is mounted a 60-h.p. gasoline engine, having its shaft placed longitudinally and geared to a cross shaft at the rear. This shaft has a sprocket wheel for chain drive to a shaft hung below the frame and carrying two rotary cutters. The cutter shaft can



Courtesy of Engineering News-Record

FIG. 1. ROTARY PLOW FOR STREETS AND ROADS, MOUNTED ON SLEDS AND HAULED BY TEAMS

A—handwheel for steering rear sled; B—Handwheel for regulating height of cutter shaft; C—Engine levers; D—Sprocket wheel; E—Engine shaft; F—Driving chain; G—22-in. cutter; H—Nose of wedge plow; I—Discharge opening; J—Snow deflector.

be raised and lowered in order to vary the depth of cut as may be required. The four-bladed cutters mounted on this shaft are 22 in. in diameter, 22 in. wide and 22 in. apart, a wedge-shaped plow being placed in front of the space between the two cutters so as to deliver the snow to them. Thus the total width of cut is 5½ ft. The snowplow is carried by the frame of the cutter shaft and is thus raised and lowered with it.

The cutters are driven at a speed of 500 r.p.m. and discharge the snow as a finely divided dust through deflecting hoods on one or both sides of the machine, the maximum width over these being 6½ ft. The deflectors are adjustable, to enable the snow to be delivered at about 3 or 4 ft. from the machine in streets or thrown to a distance of 40 to 50 ft. on suburban roads. Thus no snow is thrown against buildings or windows along the streets. In the suburban districts the residences are set back from the street, so that the snow from the roadway and sidewalks is thrown over the lawns. No objection is raised to this, as the snow is spread and does not form banks. In widening the first 5½-ft. cut, or in operating along street railway tracks, the machine is offset so as to be crowded into the solid snow while the horses travel in the cut already cleared.

Four or six horses are used, but the machine can be attached to a tractor or truck. The draft is not heavy, as only the forward sled has to break through the snow and this will go through a 36-in. depth without trouble, while the rear sled travels in the cleared path. The machine will work in snow up to 6 ft. deep, as in the case of drifts. It leaves a bed of snow beneath it so that sleigh traffic is not interfered with, this bed being usually 4 in. to 6 in. deep on municipal work.

In a test at Westmount, Que., under the direction of P. E. Jarman, city engineer, the work was to remove and distribute heavy compacted banks which had been formed by pressing back the snow from the middle of the roadway with the blade of a snow grader. Mr. Jarman gives the cost as $35.70 per 1,000 cu. yd. This included operating charges for four horses, two drivers, a mechanic, gasoline, oil, grease and repairs; also charges for depreciation, interest and insurance. Removal by hand shoveling would have cost $53.80 per 1,000 cu. yd. Further, Mr. Jarman points out that the men would have piled the snow in high banks while the machine spread it in a thin layer. As a result of the test and other experience the city purchased one of the rotary plows.

At Outremont, Que., which also has a machine, careful study of the cost was made by J. Duchastel, city engineer, and E. Lacroix, assistant city engineer. In three days (23 working hours) the machine cleared a 10-ft. path in snow 21 in. deep for a distance of 6,775 ft. at a cost of 7.2c per lin. yd., or 3.7c per cu. yd. This included fixed charges of $14 per day for repairs, 7 per cent interest and 10 per cent depreciation; also gasoline, operator, two city teams and the cost of a grader and single plow used in connection with the work. In comparison with this was the removal of snow by hand shoveling into wagons on sleighs, on a stretch of 950 ft. of the same road,

Courtesy of Engineering News-Record

SIDEWALKS BEING CLEARED BY ROTARY PLOW WHICH THROWS THE SNOW ON THE LAWNS

with the same depth and width of cut, at a cost of 23.7c per lin. yd., or 12c per cu. yd. This was done in a 10-hour day by 14 men at 25c per hour, a foreman at 35c, a city double team at 65c, three hired double teams at 60c, and four hired single teams at 30c. Sidewalks made impassable by drifts were cleared by the machine at about 50 per cent of the cost of hand shoveling. Here, as at Westmount, the advantage was noted for distributing the snow evenly in a thin layer instead of forming banks.

Hand shoveling on a mile of road at Levis, Que., cost $1,979 during 35 days' work from Dec. 26, 1918, to March 12, 1919, with from 6 to 21 men. From the figures of the work at Outremont it was estimated by H. E. Weyman, superin-

*Reproduced by courtesy of *Engineering News-Record.*

tendent of the Levis Street Railway, that this could have been done with the rotary plow at a cost of $396. On the basis of his investigation the railway company purchased a machine.

It was estimated that the machine could remove snow for a cut 5 ft. wide, 4 ft. deep and a mile long at a cost of $20.79, this being distributed as follows and being exclusive of interest and depreciation: four horses at $1.50, $6; two men at $3.50, $7; gasoline, $6; oil, $1; insurance, 79c. Hand work would require 24 men at $3 per day, which with an insurance charge of $8.13 would make a total of $80.13. On four miles of road at Levis, where the snow was shoveled back and not carted away, the cost of hand work last winter was $3,000. If the machine had been available the operating cost would have been about $750. Adding $810 for interest and depreciation the total would have been $1,560, or very little more than 50 per cent of the cost of hand labor, while the work would have been done in much less time.

Practical Applications of Selenium—III*

Its Utilization in Tele-Mechanics

By Louis Ancell

ONE of the most interesting applications of selenium consists in controlling the draft of factory chimneys by means of this method. In this case the material is reduced to its simplest expression: namely, a selenium cell placed in a cavity within the chimney located at a point where the temperature is not very high and the deposit of soot is as slight as possible; in a second cavity diametrically opposite to the cell there is an incandescent lamp designed to illuminate the cell (through the smoke). The lamp and the cell are protected from the smoke and gases by panes of glass (placed so as to be readily accessible for cleansing) which are so arranged as to avoid the action of the heat upon the selenium.[1] The cell is connected with an accumulator and with a recording milli-ampere meter placed in the office of the engineer or the foreman in charge of the forge. A mere inspection of the curve of the recording apparatus indicates immediately whether the smoke is more or less damp and consequently enables the person in charge to control at any moment the operation of the furnace and the draft of the chimney.

CONTROLLING THE RAPIDITY OF THE MANUFACTURE OF SULPHURIC ACID

Another interesting application is intended to govern the rate of speed of the manufacture of sulphuric acid in the contact process. One of the conditions required for proper functioning is the absence of sediment in the reaction tube; it is only necessary, therefore, to place a selenium cell at one end of the tube and an incandescent lamp at the other; a recording galvanometer, connected with the accumulator and with the cell enables the operator to observe the varying transparence of the atmosphere of the tube and thus to have a permanent control, the recording apparatus which is placed in the office of the operator.

APPLICATIONS TO THE MILITARY ART.

The applications of selenium to the military art are as numerous as they are varied, and the long war which has just come to an end with the victory of our arms, has enabled us to demonstrate some of the most original properties of selenium. I, myself, pointed out its importance at the beginning of the war.[2] I shall here mention only the most interesting of these applications.

To begin with wireless telephony by means of selenium and luminous waves was employed on the French front for various experiments, for which the cells were furnished by me. Furthermore, this process seems to have been employed by the Austrians upon their Alpine front, shortly after the entrance into the war of Italy. The description of this process will be given farther on. The restricted range (15 to 20 km.) and the necessity of having a rather cumbrous equipment limited the use of this system of communication, which was soon replaced, moreover, by ground telephony and by vacuum tube telephony.

TELE-MECHANICS.

We may also mention among the military applications those concerned in tele-mechanics, with the liaison formed by infra-red rays and with the locating of the enemy's batteries by means of flashes.

In the field of tele-mechanics it was my privilege to make tests before a special commission indicating the utility of such apparatus for releasing at a distance a definite mechanical action, by means of a luminous or calorific ray.

For this purpose a cell having a sensitive surface 50 by 60 mm. in extent, was connected with a relay and with a battery of about four volts; the contact of the relay was inserted in a circuit comprising a second battery of cells and an ordinary sounding device. The ensemble was placed in a box which could be readily transported. The cell was illuminated without special precaution by the luminous beam of a small automobile searchlight of about 1,000 candle power. The tests were made at night in June, 1915.

The cell was transported to distances which increased from 0 to 500 m.; by means of a screen the shaft of light could be shut off at will. Up to 500 m., which is not the extreme limit of operation, the cell was definitely influenced and the bell was sounded without trouble. . . .

MILITARY TELEGRAPHY.

The problem of the liaison between a fighting unit and a post of command, for example, by means which the enemy was incapable of detecting, led to interesting researches in military telegraphy. For this purpose I furnished in 1916 a cell having a sensitive surface of 30 by 30 mm., which when placed in the focus of a special parabolic mirror was influenced by the infra-red rays emanating from a transmitting post composed of a calorific source (an oxy-hydrogen flame impinging upon a tablet of a rare earth), a diathermic screen which was opaque to luminous rays and a parabolic mirror, and finally of a mechanical interrupter activating an a-thermic screen provided with a diathermic aperture allowing calorific rays to pass. Since this screen revolves at high speed we obtain a number of interruptions of the calorific bundle of rays corresponding to the number of revolutions of the driving motor. At the receiving post a telephone inserted in a circuit comprising the cell and an accumulator reproduces, in the form of a continuous sound, the intermittent interruptions of the calorific bundle of rays; if by means of a special de-

*Translated for the *Scientific American Monthly* from *Chemie et Industrie* (Paris). Part I appeared in our January issue and Part II in our February issue.

[1]Selenium is very sensitive both to infra-red radiations and to calorific radiations, to such a degree indeed that the mere entrance of an individual into a room causes a sufficient increase of heat to perceptibly diminish the resistance of the cell, as has been demonstrated by Dr. Guilliminot with one of the cells made by us. (*Ann. d'Electrobiologie et de Radiologie,* 1914, No. 1.)

[2]Louis Ancell, Bull. Soc. Chim., l.c.

vice we interrupt the stream of rays in such a manner as to produce Morse signals, the latter are clearly perceived at the receiving post, especially if we have taken pains to insert an amplifier in the circuit of the cell, in place of the telephone.

It will be perceived that since the calorific rays and the signals of this kind cannot be detected by the enemy it is possible to obtain a comparatively practical *liaison* by this process between two posts, either fixed or movable, several hundred meters apart.

LOCATING ENEMY BATTERIES BY FLASHES.

Another military application of selenium is connected with the locating of enemy batteries by the flashes of light from

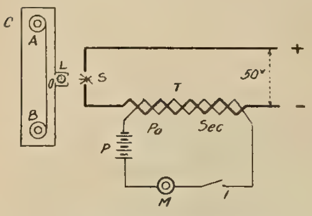


FIG. 1. LAYOUT FOR PHOTOGRAPHING SPEECH

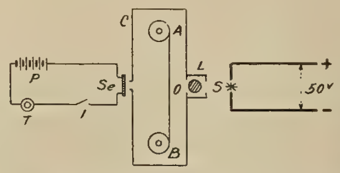


FIG. 2. REPRODUCTION OF SPEECH BY PHOTOGRAPHY

the mouths of big guns. Since the cells are sensitive even to the faintest luminous intensity and since their inertia is practically negligible, it is only necessary to place a cell at each of three different posts located a few kilometers apart, and to connect each cell (all the cells, of course, being influenced by the flashes from the enemy guns) with a suitable graphic recorder provided, as in the apparatus constructed by us for the measurement of inertia, with a time recorder. The instantaneous flash of an isolated gun would influence all three cells at the same moment; at this moment the three recording devices will indicate the variation of resistance of the cell by a corresponding deviation of the recording stylus. A phonographic comparison of the three diagrams thus obtained and a very simple calculation in trigonometry will give the location of the enemy battery. However, because of the highly improved and highly practical modern methods of locating guns by the sound, the method just described has been utilized only experimentally.

SCIENTIFIC APPLICATIONS—PHOTOGRAPHING WORDS.

Undoubtedly one of the most curious scientific applications of selenium is the reproduction of sound by means of photography. To begin with an impression is made upon an ordinary photographic film by means of luminous rays emanating from a *singing arc S* (Fig. 1) passing through a cylindrical lens *L*. The singing arc comprises an arc supplied by a continuous current. Within the circuit of the arc there is inserted the secondary coil of a transformer whose primary coil is connected with a microphone *M* and with a battery *P*. The focus of the lens *L* coincides with the surface of the film which unrolls from *A* to *B* in a dark chamber provided at *O* with a rectangular slit parallel to the lens *L*.

When one talks in front of the microphone the modulations of the voice modify the luminous intensity of the arc; the film which is unrolling with a continuous movement records these variations of luminous intensity in the form of bands which are alternately light and dark.

If now this film be illuminated by an arc such as *S* (Fig. 2), and if the luminous rays, more or less interrupted by the unrolling film, pass through an orifice made in the wall of the dark chamber and fall upon the selenium cell *Se*, then the telephone *T* inserted in the circuit will reproduce in the form of sound (somewhat weakened it is true) the variations of luminous intensity produced by the passage of the film between the arc and the cell. Here we have an original means of preserving a tangible memory of the human voice by means of a photographic phonogram. Singing and other music are produced especially well by this process.

WIRELESS TELEPHONY.

One of the most interesting applications of selenium is wireless telephony by luminous waves, because of the practical results obtained by this in the early years of the present century, when wireless telephony by Hertzian waves was in its early stages and when the new vacuum lamps utilized in the course of the great war were almost unknown.

The principle upon which the majority of the processes of wireless telephony by means of luminous waves and selenium are based, consists in general of influencing at a distance a selenium cell *S* (Fig. 3) placed at the focus of a parabolic mirror *m* and connected with a battery *P* and with a telephone *R* by the luminous rays of a singing arc *A* placed at the focus of a parabolic mirror *m*. When one speaks in front of the microphone the vibrations of the voice produce variations of luminous intensity in the arc *A*; the volume of the flame of the arc varies sufficiently to cause the arc to reproduce the sounds uttered in front of the microphone *M*. Furthermore, the variations of intensity of the luminous bundle of rays are revealed at the receiving post by corresponding variations of intensity in the current traversing the cell and the telephone. The latter reproduces, therefore, the sounds emitted in front of the microphone and transmitted in some sort by means of the light.

TELEVISION.

Both in France and in other countries attempts have long been made by inventors successfully to transmit images to a distance; some of these devices have been based upon the use of selenium. The limits of this article do not permit us to enter into details of these various processes. By way of example we will describe the main features merely of the one invented by Professor Korn in 1907. The principle of this method of transmission is almost the same in the various systems except for variations with regard to the functioning of the different organs.

The image to be transmitted is rolled in the form of a photographic film around the cylinder *C* (Fig. 4) in the interior of which is placed a thick selenium cell *R*, connected with a

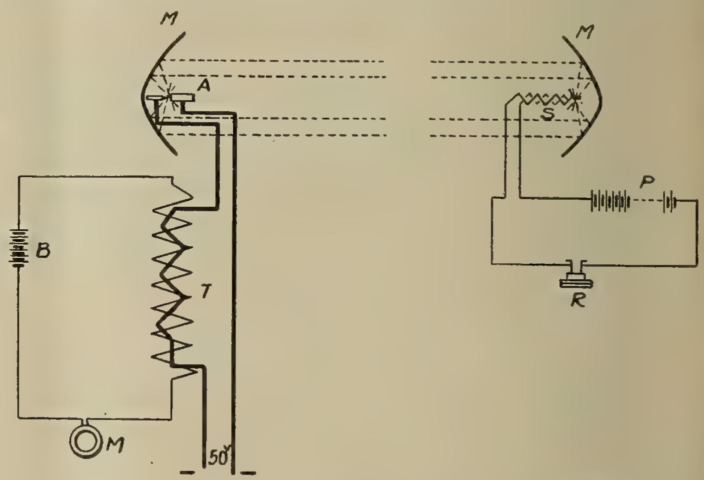


FIG. 3. WIRELESS TELEPHONY BY MEANS OF LUMINOUS WAVES

battery and with the line 1. A lens *L* whose focus coincides with the surface of the film concentrates the rays of the lamp *S* through the film *D* upon the cell *R*; in order to enable a luminous ray to traverse all the elements of the image the cylinder *C* is operated laterally.

At the receiving post a cylinder *p*, which is synchronous with the transmitting cylinder receives a sensitive photographic film. The cylinder *p* is placed in a dark chamber and is illuminated by a high frequency tube *T* supplied by the circuit *HF*; in this circuit there is a movable needle e_1 e_2

whose extremities are just opposite two small spark points. The needle is supported by a galvanometer *G* connected with the line wire and with the cell.

When the needle is displaced under the influence of the variations of the current in the cell, sparks of varying length pass between the spark points and the needle, modifying the luminosity of the tube *T* and correspondingly the photographic impression of the film. After being developed the latter reproduces the image *D* placed at the transmitting post.

An official experiment was made with this interesting device Feb. 1, 1907, upon the premises of the magazine *L'Illustration* over the telephone circuit Paris-Lyons-Paris (1024 km.) in the presence of Ministers Barthou and Simyan, the image transmitted being a portrait of President Fallière.

Among the numerous other inventors who have attempted to accomplish television we may mention MM. Armengaud (1908), Belin, Ruhmer (1909), Rignoux and Fournier (1911). The principle of these various inventions consists in projecting the image to be transmitted upon a frame covered with selenium cells, this image consisting, in general, of sections which are alternately light and dark, like a letter written in white or black. Each of these cells is connected with a galvanometer to whose movable frame is attached a small reflecting mirror at one side, which reflects the light of a lamp upon a screen placed at a given point. The different cells, some of which are illuminated while others are not, therefore throw upon the receiving screen the illuminated or the non-illuminated parts respectively, at the various points which correspond to them by means of reflective rays which are either interrupted or not interrupted by shutters. We thus obtain upon the receiving screen a somewhat blurred projected image.

PHOTOMETRY.

Finally we may mention a last application of selenium which may in some cases be of service in chemical industries—photometry.

In this case those cells which possess an extremely reduced amount of inertia are evidently indicated, and the method can as well be applied to the photometry of certain astronomical phenomena,[3] in particular of eclipses, as to the measurement of the intensity of radiation of an X-ray tube.[4]

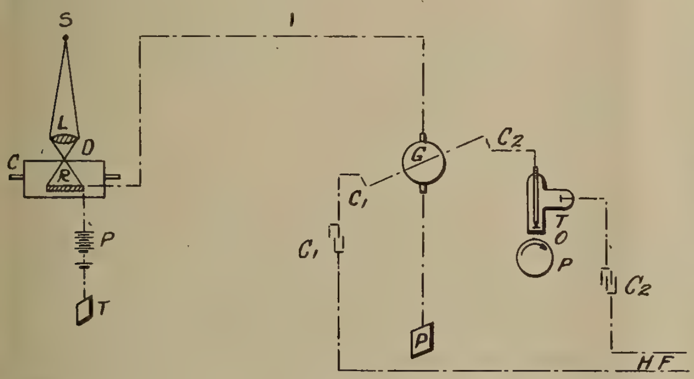


FIG. 4. TRANSMITTING PICTURES BY THE KORN PROCESS

The photometric curve (Fig. 5) which we obtained at the time of the eclipse of the sun, April 17, 1912, is an example of the interesting results obtained with a sensitive cell and with greatly reduced inertia. The cell (34 x 23 mm.) which was arranged vertically was illuminated by the solar rays reflected by the mirrors of a heliostat and connected with a 4-volt accumulator, with a milli-ampere meter and with a photographic recording galvanometer. The record began at 10:45 A. M. and ceased at 2:50 P. M. The intensities of the current in the cell were plotted in ordinates upon the curve by means of a preliminary calibration effected by means of the milli-ampere meter inserted in the circuit. The times plotted in abscissae, were determined by means of hour signals sent out that same day by the radio-telegraphic post of the Eiffel Tower. At the precise moment of an hourly signal a key was pressed manually for a period of five seconds

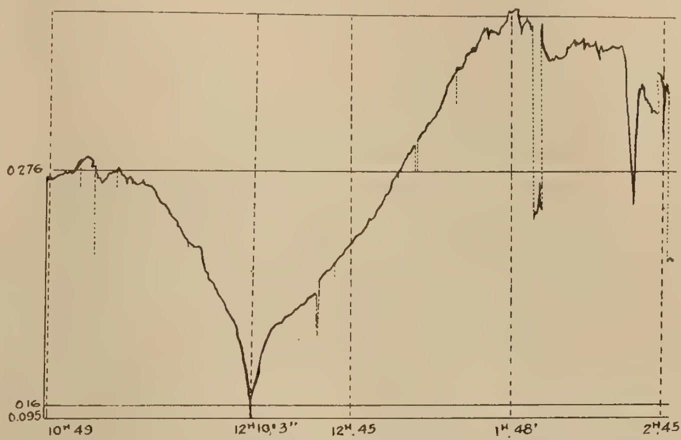


FIG. 5. PHOTOMETRIC CURVE OF THE ECLIPSE OF THE SUN ON APRIL 17, 1912, OBTAINED BY MEANS OF A SELENIUM CELL

closing a circuit comprising an accumulator and a 2-volt lamp attached to the interior of a blackened box containing the galvanometer. This lamp by illuminating a slit made in the frame of the recorder and provided with evenly spaced vertical metal wires interrupting the luminous ray threw a broken straight line upon the sensitive paper. The light intervals upon these straight lines and upon the curves made it possible to graduate the latter in intensities according to the previous calibration mentioned above.

It is evident that at the moment of totality it exhibits a very definite point of retrogression; at this moment (10 min. 6 sec. past 12 M.) the intensity read upon the milliampere meter was 0.095 ma.[5] The small oscillations visible upon the curve proceed from the vibration of the mirror of the galvanometer, the latter being due to the tremors of the ground; the more important oscillations proceed from slight imperfections of the mirrors of the heliostat and the sudden drop of the curve due to clouds passing before the sun.

This example is sufficient to show the value of the method whenever we are concerned with measuring or with comparing the variations of intensity of luminous or calorific radiations. The case presents itself in certain reactions which occur in metallurgy and chemical industry; the process is simple and is in general use, since few other substances exhibit so great a sensibility as that of selenium to radiations which are so varied, ranging from the infra-red to the ultraviolet, and including X-rays and radium rays.

THE FUTURE OF SELENIUM AND ITS APPLICATIONS.

While the use of selenium does not appear to be capable of becoming widely extended either in industrial chemistry or in the manufacture of violet colored glass, or in the vulcanization of rubber, its electro-technical applications, on the contrary, appear to be as varied as they are interesting. The various manners of employing selenium which we have just passed briefly in review give but a faint idea of the flexibility with which this metalloid can be employed in the form of cells; and while industry may hope to find in it a valuable aid in the control of the draught of smoke and of the rate of progress of a chemical reaction, we may also be allowed to hope that it will yield to our descendants the possibility of conversation and of vision at a distance.

[3] *Louis Ancel, La Photométrie de l'Eclipse de Soleil du 17 Avril, 1912 à l'Aide du Sélénium et d'un Galvanomètre En Aegistreue Photographique.* C.R.Ac.Fr., vol. 155, p. 267, July 21, 1912.

[4] H. Guilleminot. *Sur les Variations de Résistance du Sélénium Exposé aux Rayons X et aux Rayons de Radium.* Ann. d'Electrobiologie et de Radiologie, 1914, No. 1.

[5] By reason of an error made by the engraver the point of retrogression of the curve at the moment of the totality was incorrectly indicated at 10' and 30" past 12 M.

Radiation and Chemical Change*

Cause of Reactivity of Different Chemical Substances Toward One Another

By W. C. McC. Lewis

ONE of the most important problems of modern chemical science is that which deals with the origin and cause of the reactivity of different chemical substances towards one another. As an approximate measure of reactivity, regarded as a function of the nature of the material and of the conditions under which it is examined, we may take the rate or *velocity* with which a given molecular species spontaneously decomposes or reacts with another molecular species. The substances which react together are usually called the reactants, the substances which are formed as a result of the reaction being called the resultants.

For the last fifty years the guiding principle which has been applied to this problem of chemical kinetics with the greatest success is that known as *the principle* of active mass or *mass action,* first enunciated by Guldberg and Waage. According to this principle *the reactivity of a substance is measured by its concentration,* the greater the concentration the greater the reactivity. Thus the rate at which a given substance decomposes (let us suppose in the gaseous state), is proportional to its concentration at the moment considered. The velocity or rate is expressed usually as the number of gram-molecules of the substance which disappear per second in one litre of the system, the concentration itself being expressed usually as the number of gram-molecules of the substance per litre. The proportionality factor which connects the rate of the reaction with the concentration of the decomposing substance is called the *velocity constant* of the reaction. As the reaction proceeds its rate falls off owing to the diminution in the concentration of the reacting substance. The velocity constant, on the other hand, retains the same numerical value throughout the entire course of the reaction, and this numerical value may be employed to characterize the process in question.

The principle of mass action has been verified in numerous cases, which, chemically speaking, are of the most diverse character. The principle has been extended and applied, notably in connection with the thermodynamic theory of affinity and its measurement, so that, today, we may say that a very large part of physical chemistry rests upon this concept of mass action.

We must bear in mind, however, that the principle of mass action is a formal and limited statement after all. The general problem, which modern physical chemistry has to solve, is this—what lies at the basis of this formal principle? In attempting to answer this question we are brought immediately face to face with the problem of the inner molecular and atomic mechanism of chemical change. To solve this general problem completely is, at the present time, quite impossible. There are, however, certain aspects of the problem which may be usefully considered and upon which we now possess a certain degree of knowledge. Two important questions present themselves. First, is the concentration of a substance, *per se,* a sufficiently exact and complete mode of representing the chemical reactivity of the substance? Secondly, how are we to account for the well-known and very marked influence of temperature upon the velocity—and therefore upon the velocity constant—of any given reaction?

With regard to the first question, one or two simple considerations will suffice to show us that concentration alone is not an adequate measure of chemical reactivity; many substances will not react together whatsoever values be given to their concentrations. This of course is not to be taken as a criticism of the principle of mass action itself, for all that the principle professes to do is to determine the magnitude of the reaction after it has been ascertained *by experiment* that the substances considered are capable of reacting at all. What is more to our present purpose is the fact that *one and the same substance exhibits a different degree of reactivity according to the nature of its surroundings i. e.,* according to the nature of the medium in which it is dissolved. If one alters the medium one alters the reactivity of the dissolved substance. This is to be exemplified by Menschutkin's work.[1] Menschutkin observed that the series of velocity constants for one and the same reaction follows roughly the values of the dielectric capacities of the various solvents in which the reaction proceeded, although there are several exceptions to the statement which cannot be discussed now. It is evident that this electro-magnetic property, the dielectric capacity of the medium, has something to do with the rate. From these facts we infer that the principle of mass action correctly accounts for the rate of the reaction once it has started, but is unable to account for the influence of different solvents upon one and the same reaction. We arrive therefore at the important general conclusion that *chemical reactivity depends not only upon concentration but also upon the environment in which the reaction proceeds.* Now, how are we to express this dependence upon the environment? To get some idea of this we must return to the second of the two problems which we set before us, namely, that dealing with the influence of temperature upon the rate of reaction.

It has been shown as a result of numerous investigations that the velocity constants of reactions are very sensitive to temperature, a rise of 10 degrees causing a marked increase in the velocity constant. If we are considering ordinary room temperatures we may say that a rise of 10 degrees causes the velocity constant to treble or even quadruple itself. That is, there is an increase of 300% in the velocity for an increase of only 3% in the absolute temperature. Now this very marked increase in the velocity of the reaction cannot be accounted for simply on the ground of an increase in the speed of movement or translation of the molecules, for it can be easily shown that a rise of 10 degrees increases the frequency of collisions between molecules by only about 2 per cent, whereas the increase in reactivity is of the order 300 per cent. It is fairly certain, therefore, that the effect has to do with *the internal energy of the molecules.*

On the basis of the socalled Quantum theory of specific heats it is known that when heat is added to a body the energy distributes itself unequally among the various molecules, so that while some receive no energy at all others receive a quantity which might be called the average amount, and a few molecules receive excessively great amounts of internal energy. It would seem therefore that the influence of temperature upon reaction velocity is to be sought in the existence of a relatively small number of the total molecules present which have received an abnormally large quantity of internal energy. The fact, that many reactions occur with a *finite* and measurable velocity, shows us that *all* the molecules are not in the same chemical state. If they were, the speed of the reaction would either be zero or practically infinite. This consideration also leads us to look for a certain differentiation between the molecules of a substance as regards internal energy content.

A considerable advance in the problem of the relation of the velocity of a reaction to the temperature was made by Arrhenius[2] in 1889, who suggested that the velocity constant was an exponential function of the temperature.

*Republished from *Scientia.*

[1]Menschutkin, *Zeitschr. für physikalische Chemie,* 6, 11 (1890).

[2]Arrhenius, S., *Zeitschr. für physikalische Chemie,* 4, 226 (1889).

The equation of Arrhenius involves an empirical constant quantity denoted by A. The term A is characteristic of a given reaction. If we know by experiment the numerical value of A and the value of the velocity constant at any single temperature we can then easily calculate, with the help of the equation of Arrhenius, the velocity constant at any other temperature. The term A can be shown to be an energy term and is numerically very large.

This expression of Arrhenius has been applied to numerous reactions and has been found to hold with a considerable degree of accuracy. But it must be clearly understood that the expression itself is largely empirical although Arrhenius has attempted to find a theoretical basis for it. The importance of this equation of Arrhenius for our present purpose lies in the fact that there must be some close connection between the mechanism of a chemical reaction and the influence of temperature upon the velocity constant. In short, what we are attempting to do is to visualize some reasonable mechanism for the effect of temperature upon the velocity constant of a given decomposition, and then to transfer the idea to the mechanism of the reaction itself as it proceeds at any given constant temperature.

The most important suggestion yet made in connection with the effect of temperature upon reaction velocity (which finds its formal expression in the equation of Arrhenius), is that of Marcelin[3] (1913), which was rendered more exact later by Rice.[4]

Marcelin and Rice treat the effect of temperature from the standpoint of statistical mechanics. The physical idea underlying it is that a molecule in the mean or average state, that is, a molecule containing the *average* amount of internal energy is chemically *non*-reactive. Since however, the internal energy is distributed unequally over a large number of molecules, it must happen that a small number will receive an abnormally large amount. According to Marcelin, when the internal energy of a molecule reaches or exceeds a certain high value, called the *critical energy*, the molecule is then capable of reacting in a chemical sense. The *additional* energy which a molecule in the mean or average state must receive in order to make it reactive in the above sense is called the *critical increment*. We shall denote this quality by the letter E, it being understood that E is expressed in calories and refers to one gram-molecule as the unit of mass. If there are N actual molecules in one gram-molecule then E/N represents the critical increment per single molecule. In the case of the decomposition of a single molecular species,—the dissociation of gaseous iodine, for example, into its atoms,—the activated molecules do not possess a real existence, for the act of activation, *i. e.*, the act of reaching the critical state is identical with the act of separation of the atoms which may be thus considered as free for the first time. On the other hand the activated molecules of hydrogen iodide gas can exist; when one such molecule collides with another similarly activated they react together giving rise, as is well known, to hydrogen and iodine gases. On the Marcelin-Rice view, as adopted by the writer, the rate of decomposition or dissociation of a gas, *i. e.*, a *uni*molecule reaction, is identical with the number of molecules which attain the critical state per second. On the other hand the rate at which hydrogen iodide decomposes is identical with the number of collisions per second between pairs of activated molecules, for it is known that two molecules are simultaneously concerned in this reaction, *i. e.*, the process is *bi*molecular. In both cases however, it is necessary that a certain increase in the internal energy of the molecular species shall have taken place antecedent to the observed chemical reaction itself.

It is not proposed to enter into the mathematical development of this view of the activation of molecules which has been carried out by Rice on statistical lines. Suffice it to say that, on this basis, we arrive at the conclusion that the velocity constant should be an exponential function of the temperature.

In fact we arrive at an expression which is of exactly the same form as that suggested by Arrhenius and must therefore be in as good agreement with experiment. The considerable advantage is, however, that the physical meaning of E which now replaces A is quite definite, authough, of course, the whole argument is based on a generalized treatment which does not solve the problem of actual molecular structure, beyond the fact that in the process of activation the atomic groupings inside the molecule are pulled apart to a certain distance, thereby loosening the bonds between the atoms and permitting certain lines of force to attach themselves to other neighboring molecules. It should be pointed out that sensibly the same view of the atomic mechanism of chemical activation had already been expressed by Baly,[5] who pursued a totally different line of reasoning, based upon observations of the absorption band spectra (exhibited in the ultra-violet region) by various substances under different conditions. It is highly satisfactory that two distinct lines of thought should have led to the same general conclusion.

We have now, however, to push our inquiry one step further. We have seen that the concept of the activation of a molecule by an increase in its internal energy up to the required limit is sufficient to account for the fact of chemical velocity, and the influence of temperature upon the velocity constant. The question now remains in what manner does the molecule obtain this extra increment of energy? What is the ultimate source of this, and indeed of all, molecular and inter-atomic energy, both kinetic and potential? Whatever hypothesis we may adopt it must be such as to permit us to arrive finally at the Macelin-Rice result, for this, as we have seen, possesses sound experimental verification.

In the writer's opinion, the most plausible hypothesis[6] is, that *radiation*, that is energy of the radiational type, *is the ultimate source of all energy which makes chemical reactivity possible.* In the case of ordinary or thermal reactions, as they are called, that is reactions which proceed at ordinary temperatures, the effective radiation is of the short infra-red type. Such radiation is necessarily present throughout any material system in virtue of the temperature of the system. (It is only at absolute zero that we can conceive of radiation as being absent). In the case of reactions, which proceed measurably at high temperatures only, the effective radiation belongs to the shorter wavelength region, namely the visible or ultra-violet part of the spectrum.

The idea that radiation of all wavelengths interpenetrates matter is of course not new. The whole physics of radiation depends upon that. What is particularly important to observe in the present instance is that the radiation, to which is ascribed this fundamental rôle as the *fons et origo* of molecular energy and therefore of chemical reactivity, is essentially temperature radiation. That is, the temperature of the radiation is the same as that of the matter which it interpenetrates. In fact, the temperature of the substance is directly due to the presence of radiation which is being continually absorbed and emitted by the molecules of the material. This postulate, that the radiation which brings about chemical change is at the same temperature as the matter itself, means that we are considering a very different state of affairs from those to which we give the name photochemical reactions. In the latter a source of radiation, usually of the visible or ultra-violet type, external to the material system, emits radiation which is absorbed by the system, thereby bringing about chemical change. Such effects, due to short waves, have long been familiar. In photochemical arrange-

[3]Marcelin, R., *Comptes Rendus*, 157, 1419 (1913); *ib.*, 158, 116, 407 (1914); *Annales de Physique*, 3, 120 (1915).

[4]Rice, J., *British Assoc. Report*, p. 397 (1915).

[5]Baly, E. C. C., *Journ. Chemical Soc.* (London), 101, 1469 (1912); *Astro-physical Journ.*, 42, 1 (1915).

[6]Lewis, W. C., McC., *Journ. Chemical Soc.* (London), 105, 2330 (1914); *ib.*, 109, 796 (1916); *ib.*, 111, 457, 1086 (1917); *ib.*, 113, 471 (1918).

ments, however, the temperature of the radiation is very high, while the temperature of the material upon which it acts is low. In the case which we are considering, on the other hand, the temperature of the radiation and of the matter is the same.

Having postulated the identity of temperature for the matter and the radiation we are at once justified in applying Planck's Quantum Theory of radiation which deals with such conditions. It is impossible to enter into any of the details of this modern theory of radiation. Suffice it to say that, according to the Quantum Theory, radiation consists of small units of radiant energy, called quanta, and that radiation may be absorbed or emitted by molecules of matter one quantum at a time. This, at any rate, is the very simplest statement that can be made to convey in a "rough and ready" way the concept of quanta. These small units or quanta are each proportional to the vibration frequency of the radiation which they represent.

Briefly, the radiation hypothesis of chemical reactivity states that *the rate at which a substance decomposes or interacts depends not only upon its concentration, but simultaneously upon the density of that type of radiation which the substance can absorb*, for of course, it is only the absorbable radiation which can be effective. This statement is virtually a new or modified principle of mass action. It does all that the older principle is capable of doing, and at the same time is capable of taking account, at any rate to a large extent, of the effect of temperature and the influence of environment upon the velocity constant and therefore upon the reactivity of the molecular species considered.

Naturally the idea that radiation could bring about ordinary or thermal chemical change is not new. It must have occurred to almost anyone who was familiar with the facts of photochemistry. Photochemistry, in fact, is a special case of general radiation chemistry. The important thing is, however, the introduction of the Quantum Theory which allows us to express the radiation hypothesis of chemical reactivity in a more or less quantitative form. Without going into details the radiation hypothesis leads to the conclusion that the velocity constant of any ordinary reaction should be an exponential function of the temperature in complete agreement with the conclusions of Marcelin-Rice and Arrhenius. In place of the term E in the Marcelin-Rice expression, we now find a term denoting the total number of quanta absorbable by one grammolecule, which leads at once to the conclusion that the critical increment of a single molecule is just one quantum of the absorbable type of radiation. This is identical with the well-known law of the "Photochemical Equivalent" first enunciated by Einstein.[7] Einstein's law takes on therefore a new and wider significance. If, therefore, we know the type of radiation (*i. e.*, the wavelength or frequency), which the substance is capable of absorbing (in the proper part of the spectrum) we can calculate the effect of temperature upon the velocity constant. Conversely, from the observed effect of temperature upon the velocity constant, we can calculate the wavelength of the radiation which the substance is capable of absorbing and by means of which it is able to exhibit chemical reactivity. It has been found by the writer that such calculated wavelengths agree well with the known positions of absorption bands possessed by substances. At the present time the chief difficulty is the lack of spectroscopic data, as the velocities of reactions have been measured in numerous cases in which knowledge of the corresponding absorption spectra is entirely wanting. So far as the data are available, however, the radiation hypothesis has been substantiated. Further, from such data it has been shown that the *heat* of the reaction[8] can be calculated, and this conclusion has likewise received a certain amount of experimental verification.

Again, the radiation hypothesis requires that the velocity constant of a reaction should depend upon the cube of the *refractive index* of the system for the wavelength absorbed, *i. e.* for the wavelength which is causing the chemical change. On the classical electromagnetic theory of radiation it is well known that there is a very close connection between the refractive index and the dielectric capacity. Hence on the radiation hypothesis we would expect a close relation between the velocity constant of a reaction and the dielectric capacity of the system in which the reaction proceeds. It has already been pointed out that the results obtained by Menschutkin and others entirely support such a conclusion. At the present stage this and other conclusions have a qualitative rather than a quantitative basis, and there are a number of *apparent* exceptions to the rule. The application of the Quantum Theory of radiation to chemical reactivity is very recent, and especially under present conditions it is impossible to carry on the necessary research work which the hypothesis suggests. The field, however, is very promising and the results so far obtained are sufficient to give very strong *prima facie* grounds for the general truth and applicability of the concept that the radiation, necessarily present in material systems (in virtue of their temperature) is the fundamental source of chemical change of all kinds.

[7] Einstein, A., *Annalen der Physik*, iv., 37, 832 (1912).

[8] Lewis *loc. cit.*

SODIUM FLUORIDE AS A WOOD PRESERVATIVE

TESTS made years ago at the Forest Products Laboratory indicated that sodium fluoride might be successfully used as a wood preservative, because it had high toxicity, was not injurious to metal, and was convenient to handle. Laboratory tests alone, however, are never sufficient to establish the value of any material as a wood preservative; actual service tests, even though they require years to complete, are also needed.

In order to obtain comparative durability records, the laboratory in 1914 placed sap-pine ties treated with sodium fluoride, together with ties treated with zinc chloride and creosote, in one of the mines at Birmingham, Alabama. Similar service tests were also started at this time on red oak ties placed in the tracks of the Baltimore and Ohio Railway Company.

After five years of service the mine ties which were treated with sodium fluoride have been found in as good condition as those treated with zinc chloride, both showing very little deterioration. The creosoted mine ties apparently were in still better condition, while the untreated ones were in various advanced stages of decay. The red oak railway ties treated with sodium fluoride were practically all sound, as were those treated with zinc chloride, whereas a large percentage of the untreated oak ties had been removed.

Both of these tests, as well as others started later, must continue for a number of years yet before the relative value of the sodium-fluoride treatment for ties and timbers is definitely known.

NEW TYPE OF CLAY-DIGGING MACHINE.

A MACHINE has been designed to replace the usual method of extracting clay (viz., excavators, breakers, blasting), especially the rich plastic clay used in the refractories industry. The machine consists essentially of a rack 8 to 10 m. long running between guide-rolls and resting on a scaffolding traveling along the upper edge of the clay being worked. Underneath the rack is a box-shaped cutting tool of rectangular section. The strip of clay extracted by this tool is cut up into slabs by a second knife acting automatically. The whole is driven by a 4-10 h.p. electric motor or gasolene engine, one man being required for operating. Output: 50 to 200 cbm. clay in 10 hours.—*Technische Zeitschriftenschau*, Nov. 15, 1919. Abstracted through *The Technical Review*.

Testing Seeds with a Thermometer

Infection or Debility Shown by the Temperature Developed

By George J. Peirce, Professor of Plant Physiology, Stanford University

HOW can the farmer test the quality of his seed-grain, corn and alfalfa? How can one find out quickly and cheaply the quality of the garden-seed offered in gay envelopes by grocer and druggist? How can the qualities of grain cargoes coming into the great ports be ascertained without great expenditure of time and money?

These are questions not of idle curiosity merely. They are practical questions which have been answered in certain instances, and the method is of wider usefulness.

When Sir James Dewar, one of Faraday's successors at the Royal Institution, in London, was liquifying air and solidifying carbon-dioxide and various other gases, he required containers which should not only mechanically hold his products but should at the same time insulate them. He made double-walled flasks, bottles, and cylinders of glass, electroplating the inner and outer walls of the outer and inner bottles, and exhausting the air between them. These double-walled vessels are known in chemical and other laboratories; but they are known generally as thermos bottles, or "icy-hots." A thermos bottle, with its shiny, nickel-plated metallic case, is essentially a silver-plated vacuum. The principles involved in the thermos bottle or Dewar flasks are simply these: that heat-waves do not traverse a vacuum, though they will pass through air, water, etc.; and that they, like the waves of light and sound, may be reflected by mirrors. The silver-plating furnishes the mirror-like surface, and greatly increases the efficiency of the thermos or Dewar bottle as an insulator.

In many laboratories of botany, all over the world, students have been shown that germinating peas, opening calla-blooms, and various other living parts of plants, liberate heat. The containers and insulators formerly used were ordinary vessels of glass, wrapped in cow-hair felt, absorbent cotton, etc., all of which are relatively poor insulators. Of late years, however, Dewar vessels and thermos "refills" have replaced the cumbersome and unsatisfactory wadded vessels, and instead of the low and misleading temperatures formerly taken, we now know that peas have their comparatively high and "normal" temperatures just as human beings, cows, horses, and other animals have. The "normal" temperature of an adult person is 98.6° Fahrenheit. If a person's temperature, as taken in the mouth, under the tongue, is over 98.6°, the physician recognizes fever and looks for the place and kind of infection; or if it is under, then he seeks for the reason for the debility thus indicated. By putting a known weight of good peas with an equal quantity of cooled boiled water into a Dewar flask or thermos bottle and keeping this loosely corked or cotton-plugged for two days, one should find the thermometer indicating a temperature inside the flask considerably higher than that of the room. Thus, in a certain experiment 2¾ ounces of American Wonder extra early garden peas were nearly 20° warmer at the end of two days than when they were put into the insulator. But among these peas four were found that were decaying. Examination showed them to be weevily. The weevil holes were infected and this infection caused the abnormally high temperature. On the other hand, another experiment with an equal quantity of peas four years old showed a decidedly lower temperature in the same length of time. In other words, the vigor and soundness of these two lots of peas was plainly indicated, in 48 hours, by the temperatures developing in these test lots in Dewar or thermos bottles. The temperature of the fresh peas was above normal because they were weevily and fungus or bacteria infected; and the temperature of the old peas was low because they were weak from old age. But in a bottle of four-year-old and carefully sterilized hemp seed no temperature would develop because hemp seed loses its germinating power in about two years. Clover seed yields a normal or sub-normal temperature according to its freshness; but if it is contaminated or infected seed, it will have "fever."

Thus the vitality, germinating and growing power, cleanness, and soundness of seeds can be determined, according to the kind of seed, by the very simple test indicated in a considerably shorter time and with much less trouble than would be required to make any other germination test in soil or what not. But just as there are warm and cold-blooded animals, so there are quick sprouting and slow sprouting seeds. But if one knows the normal behavior of seeds, one can tell at once, by the abnormal temperature developing in a Dewar or thermos bottle containing them, whether a given lot is good or bad. The wisdom of buying or sowing such seed is indicated very promptly and definitely.

These thermos bottle tests are not limited in applicability to seeds, for some of the qualities of milling grains, hay, etc., can be ascertained swiftly and accurately in this way. If a given lot of wheat intended for the flouring mills is found to contain insects, it can be fumigated and thus relieved of these pests. But if it contain fungus or bacteria besides the insects, fumigation will not sterilize the grain. The quality of the flour, and its value in bread-making, depend in part on the grain being clean, that is, free from pollution of any sort. Infected flour will not make bread which will be satisfactory in its rising power, texture and flavor. Furthermore, imported grain may bring foreign grain and other diseases into the country, and the danger of so doing can be ascertained by diagnosis based on temperature tests.

Some of these possibilities have been realized in practice,[1] but the use of the Dewar or thermos bottle tests of grain, seeds, etc., can be greatly extended from a laboratory of "pure science," where, like the thermos bottle, it started, to commercial uses.

SPEED OF SOUND-PULSES IN PIPES.

WRITING in the *Physical Review* for August, 1919, A. L. Foley describes experiments to determine the speed of sound in pipes. The sound was measured by a photographic method; short tubes were used, placed near a spark source. An instantaneous photograph was obtained of a sound-pulse, part of which had come through a tube, while another part had come through free air. In this way the effect of short tubes of various sizes was determined when their near ends were from 1 to 5 cm. from the spark. Two photographs are reproduced which show that in some cases the pulse may travel faster through a short tube than in free air, and faster through the smaller of two tubes than through the larger. The speed through a tube was found to depend chiefly on the intensity of the pulse as it entered the tube, and this was true even when the motion of the air as a body was prevented by a thin collodion membrane stretched across one end of the tube. The mean speed was less the longer the tube. The paper includes an historical survey of the work done on the speed of sound in pipes, with a two-page table of results obtained.—From *Science Abstracts*.

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[1]Peirce, G. J. A new respiration calorimeter. *Botanical Gazette*, vol. 46, 1908. The liberation of heat in respiration, *Botanical Gazette*, vol. 53, 1912. A study of the germinating power of seeds, *Botanical Gazette*, vol. 58, 1914.

The Capillary Circulation*

How Are These Blood Vessels Dilated and Contracted?

By W. M. Bayliss, F.R.S., M.A., D.Sc.

Professor of General Physiology, University College, London.

ALTHOUGH the part played by the small arteries, arterioles as they are usually called, in regulating the height of the blood-pressure and the supply of blood to the tissues of the various organs is fairly well known, that of the capillaries and the veins remains more obscure. The fact that the arterioles possess a muscular coat of relatively considerable thickness, while the capillaries consist merely of a single layer of epithelial cells, renders the mechanism of contraction and dilatation of the former easy to realize. Their nervous supply has also been worked out in some detail, and the facts of their active changes in calibre under the stimulation of various nerves and under the influence of different kinds of drugs and other chemical substances are generally admitted.

The veins also possess a muscular coat, but of much less thickness than that of the arterioles. Some evidence exists that they are capable of changes in calibre; but the object of the present article is to consider rather the facts that have come to light in recent times with regard to the properties of the capillaries, together with the consequences, theoretical and practical, that follow them.

The difficulties in supposing that the capillary blood-vessels have the power of altering their calibre independently of the pressure of the blood entering them appear to be largely due to the absence of a muscular coat. On the other hand, a fairly copious supply of nerve fibres to them has been described, and we know that cells other than muscle cells can change their form when stimulated. The pigment cells of the skin in fish and frogs may be mentioned, and the spherical forms assumed by the amoeba and the leucocytes are familiar. Thus the absence of a muscular coat in the case of the capillaries does not warrant a denial of the possibility of active changes in calibre in the latter.

If the reader will examine, under a low power of the microscope, the circulation in the web of the frog's foot—and there is probably no more interesting thing in the whole of physiology—he will notice how great is the volume of the capillaries compared with that of the veins and arteries. He will see that the rate of the flow of blood in the arterioles is, accordingly, very much greater than that in the capillaries; and, remembering that the friction is proportional to the velocity, he will realize the great effect that changes in diameter of the arterioles have on the pressure on the arterial side of the system. But he will also appreciate how large a volume of blood can be contained in the capillary region, and that a comparatively small increase in the diameter of the capillaries, if present in a large part of the body, will suck up, as it were, a great proportion of the blood present in the circulation. The importance of this fact is that the amount flowing into the heart from the great veins will be less, and therefore also that driven out into the arteries on contraction of the ventricles. Hence there will be a fall in blood-pressure and deficient supply to the tissues generally. Thus, although the capillaries may be wider, the current through them will be diminished by the decrease in driving pressure, in addition to the lower rate of flow involved in their increased width. Under ordinary circumstances, as described by Lister and by Langley, some of the capillaries are more or less empty of blood, and become filled only when dilatation occurs. This is an additional way in which blood is accumulated in capillary networks. This fact has recently been further investigated by Krogh, who shows that, in resting muscle, only a small number of the capillaries are filled with blood. In activity, a greater or less proportion of the remainder becomes dilated and conveys a current of blood. According to his experiments, it requires a fairly high pressure to open up the collapsed capillaries; so that, if an increased supply of blood is needed by an organ, it is necessary that an active dilatation of the capillaries should occur, as well as one of the arterioles. It appears that, if the latter alone were to take place, a comparatively small increase in blood-supply would be provided. If the capillaries alone dilate, there is no increase in total supply, or very little, and the blood which continues to flow will be greatly reduced in rate with a tendency to stagnation, with rapid loss of its oxygen. This condition will be exaggerated if the arterioles simultaneously constrict, as happens under the action of histamine.

That the capillaries are not merely passively distended or depleted according to the diameter of the arterioles supplying them is indicated by the common experience of two different effects of external cold on the skin. The color of the skin in white races is almost entirely due to the blood in the capillaries. When the blood supply is cut off, the skin becomes white and cold. This may sometimes happen as the result of the constricting effect of cold on the arterioles; but there are also two familiar states produced by cold which are associated with increased depth of color, and therefore with a greater content in blood. In one of these, the skin is red and warm; in the other, on the contrary, it is blue and cold. It is clear that the warmth in the former cases must be due to an increase in the current of warm blood flowing through the capillaries, and this can only be brought about by dilatation of the arterioles and capillaries. The capillaries are thus filled with a rapidly renewed current of fresh warm blood. In this way, the skin is protected from the deleterious effects of cold. A compromise must be effected between the increased loss of heat from the body and the protection of the skin. It will be remembered that one of the means of getting rid of excessive heat is by dilatation of the vessels in the skin. What is the state of affairs when the skin is blue? Bearing in mind the fact that the color of the blood in the veins appears to be blue when looked at through the skin, we realize that this is the color assumed when oxygen has been lost. The blue color of the blood in the capillaries must be due, then, to its having lost more oxygen than it does when the skin is red. Although the capillaries are dilated, the current through them must be decreased, and this state can only be explained by an expansion of the capillaries independent of that of the arterioles, which are probably constricted. The coldness of the skin is readily explained on the basis of the slow circulation through it. An exaggeration of this blue state of the skin may be observed in certain pathological conditions, and appears to be easily brought about by exposure to cold in such cases.

With regard to more definite experimental evidence of active change in the capillaries, we may note the difficulty of excluding passive effects due to changes in the arterioles. A dilatation in these vessels would raise the pressure at the place where they become capillaries, and naturally distend them to some extent. Lister in 1858 described dilatation of the capillaries in the frog's web under the action of chloroform and other agents. Roy and Graham Brown in 1880 confirmed this observation, and believed that they had excluded the effect of the simultaneous dilatation of arterioles by the fact that if reflex stopping of the heart was brought about, so that the arterial pressure fell to zero, the dilated capillaries did not empty.

*From *Science Progress*.

This, however, is not completely convincing, because the elastic reaction of the capillaries might not be sufficient to empty them after they had been stretched. If the passive stretching had caused an elastic reaction, it is difficult to see why the capillaries did not empty themselves back into the arterioles where the pressure was zero. Better evidence of independent action on the part of the capillaries is afforded by the observation of these investigators that the diameter of different capillaries is not in direct proportion to the arterial pressure. Two capillaries lying side by side may require very different external pressure to obliberate them, and, after a pause, that one which previously collapsed under the lower pressure may now require the higher one.

In 1893, Worm-Müller had shown that large quantities of blood could be injected into dogs without much rise of blood-pressure. The blood remained in the circulation, and post-mortem observations did not reveal a distension of the arteries and veins of sufficient degree to accommodate it. The conclusion was drawn that it was accumulated in the capillaries of the body generally. The adjustment is doubtless brought about by a nervous reflex. It may be that a sufficient explanation lies in dilatation of the arterioles and the resulting passive distension of the capillaries. If this be not accepted, and Krogh's results cast doubt on the acceptability of the explanation, we must assume a direct nervous control of the capillaries by vaso-dilator nerves.

Severini described experiments on the empty capillaries in excised tissues in which oxygen caused narrowing; carbon dioxide widening; but Roy and Graham Brown failed to confirm the observations.

Other observations on capillary dilatation might be quoted but it will be seen that, so far, satisfactory experimental evidence of an independent activity on the part of the capillaries is wanting. This was not afforded until the experiments of Dale and Richards in 1918. Dale and Laidlaw in 1910 were struck by the puzzling action on the blood-pressure of a base, histamine, obtained by removal of carbon dioxide from the amino-acid, histidine, a constituent of most proteins. In the dog, cat and monkey, a marked fall of blood-pressure is produced by very small doses. Now, in the case of certain other drugs having this effect, depression of the heart being excluded, it was known that dilatation of the arterioles was produced, and the explanation of the fall of blood-pressure was easily explained by decrease of peripheral resistance. But tests of the action of histamine on various kinds of smooth muscle, including that of the arteries, showed that it caused *contraction*, and therefore narrowing of the arterioles, an effect which by itself alone would produce *rise* of blood-pressure. By a number of ingenious experiments, the details of which cannot be given here, Dale and Richards showed that histamine causes a widespread dilatation of the capillaries, independent of its effect on the arterioles, which are constructed. It is evident, therefore, that the capillary effect is great enough to overpower that of the arterioles. How is the fall of blood-pressure produced? It seems improbable that a dilatation in such a wide bed as the capillary district, even in normal conditions, should have any marked effect in decreasing the peripheral resistance, especially when the arterial constriction has reduced the blood flow to a low degree of magnitude. The result must be due to removal of blood from actual circulation, an interpretation confirmed by the examination of the heart, which is seen to be empty of blood. In fact, the blood, soaked up by the capillaries as by a sponge, takes no mare part in the general supply of the organs with fresh oxygenated blood than if lost by hemorrhage. In this work, the fall of blood-pressure caused by very small doses of adrenaline in certain conditions was shown to be due to its dilator action on the capillaries.

The practical interest of these experiments lies in the fact that histamine is one representative of a group of substances obtained by disintegration of the protein molecule. In the state of "shock" brought on by extensive injury to tissues, especially top muscle, whether by shell wounds or by surgical operations, observations made at the casualty clearing stations in the late war showed that a state of the circulation similar to that produced by histamine was present. The obvious connection between severe shock and massive injury suggested experimental test. Col. Cannon, of Harvard University, and the present writer found that injury of the thigh muscles in anaesthetized cats and dogs brought on a condition like that of wound shock, and we were able to show that it was not due to irritation of nerves, but to the passage into the blood of some chemical product of the injured tissue. The fact that the state, whether accompanied by hemorrhage or not, owes its dangerous character to the want of blood in circulation, pointed to the treatment which alone was found successful—namely, the filling up of the circulation by transfusion of blood or of some appropriate artificial solution, such as gum arabic in saline.

In regard to the nervous supply of the capillaries, some recent observations by Krogh are of importance. He shows that it is possible, by touching with a glass needle over the situation of a closed capillary in the frog's tongue, to make this vessel dilate, and that the extent to which the dilatation spreads depends on the strength of the stimulus. A similar local effect can be obtained on an arteriole. Degeneration of the nerves to the tongue or the application of cocaine very nearly abolishes the effect, and what remains is sharply localized to the point stimulated. The conclusion is drawn that the spreading of the effect is due to an axon-reflex in sensory fibres, analogous to that suggested by myself (1901, p. 196) for the case of the vaso-dilatation produced by stimulation of the peripheral ends of sensory nerve fibres.

There remains for brief discussion another aspect of the capillary circulation which has important physiological and pathological relations. In the shock produced by histamine, and also in that of wounds in man, it was found that not only was the blood in effective circulation diminished, but what was in circulation had become more or less concentrated by loss of plasma. To understand the cause of this phenomenon, we must consider the evidence as to the permeability of the capillary wall. It is a familiar fact that, when blood is lost, fluid is taken up from that in tissue spaces in order to restore the volume of the blood as far as possible. What is the nature of this fluid? It was shown by Scott that, although the lymph outside the blood-vessels contains proteins, that which enters the blood is devoid of them, consisting only of a solution of the salts and diffusible substances of small molecular size, such as glucose and amino-acids. In other words, the normal capillary wall is impermeable to proteins. If, then the proteins of the blood possess an osmotic pressure, this will be manifest in a tendency to absorb water from the outside. Starling showed that they have such an osmotic pressure, and that it reaches the value of about 35 mm. of mercury. This may be regarded as the force tending to draw water into the blood. But on the arterial side of the circulation, the pressure inside the blood-vessels is about 150 mm. of mercury. This is opposed to the osmotic pressure, and the excess pressure causes the filtration of fluid (=lymph) outwards. Following the blood-pressure as it falls in its course from the arterioles to the capillaries, we find that the pressure inside the latter only amounts to some 10 mm. of mercury. This is less than the osmotic pressure of the proteins, and water is absorbed from the outside. The two processes, however, do not completely compensate one another, and a certain quantity of the lymph is drained off by the lymphatic vessels, being ultimately returned to the blood by the thoracic duct. When we inject into the veins a solution containing salts or glucose only, we decrease the osmotic pressure of the proteins by dilution, more pressure is available for filtration, while the place where reabsorption begins is pushed farther towards the veins, so that a diminished area is in activity. The result is that the fluid injected leaves the circulation rapidly, and the blood returns to its diminished

volume. This agrees with clinical experience. If, however, we add to our injection fluid a colloid possessing an osmotic pressure of the correct value, there is no tendency to loss by increased filtration, and if the permeability of the capillaries is normal the increased blood volume is permanent. The present writer has shown that the addition of 6 or 7 per cent. of gum arabic to the 0.9 per cent. sodium chloride serves this purpose, and such a solution was in extensive use during the later period of the war.

Incidentally, it may be remarked that the filtration of protein-free liquid from the blood-vessels owing to the pressure therein is the view most generally accepted as the first stage of the production of urine.

But there is another way in which increased exudation from capillaries may be brought about. Suppose that the walls become permeable, not only to salts, but also to colloids. There is then no osmotic force to oppose filtration, because the osmotic pressure of the proteins cannot be effective. Now, such an effect is produced by histamine and other products of tissue destruction. If it has reached a high value by prolonged action of the toxic substance, it cannot be restored to normal. Accordingly, in late and severe stages of wound shock, neither blood nor intravenous gum-saline is effective. The liquid escapes from the blood-vessels in a comparatively short time and the blood-pressure fails to its former low level. The occurrence of this condition is shown by the coincidence of a low blood-pressure with a high haemoglobin content of the blood, indicating loss of fluid, whereas normally the low pressure would be associated with dilution. This latter was, in fact, recognized as a favorable sign. If the change in permeability has not become too great, the introduction of blood or gum-saline may restore the normal state.[1]

A similar action to that of histamine on the permeability of the capillary appears to be exerted by prolonged deficiency of blood-supply, probably owing to want of oxygen. The low pressure of shock in itself exaggerates the direct effect of the tissue toxins.

In certain regions of the body, such as the liver, and to some extent, the intestines, the capillaries are normally more permeable to proteins than in other regions, and lymph is accordingly more abundantly formed in such regions. It also contains a certain amount of protein. But, of course, the pressure in the portal vein is much lower than that in the arteries, and the lymph produced also ultimately finds its way back into the blood.

ANATOMICAL MODIFICATION OF ROOTS BY MECHANICAL ACTION.

The well known naturalist, Mme. E. Bloch,[2] recently presented before the French Academy the results of her experiments concerning external compression of the stalks and roots of various plants. The work was done with the object of reproducing by experiments certain dissymetries of structure which had been observed upon plants which have made their way through stony ground or through the fissures of rocks. It was the investigator's purpose also to study those factors which affect roots or stalks when they develop in various milieu (air, earth, water), and present for this reason those various anatomical differences which were first pointed out by Constantin.[3]

One of the first things observed was that plants having compressed roots and rhizomes—which were collected in stony territory—had flowered and fruited in a perfectly normal manner. It was noted secondly that all plants which had been developed from seeds and later subjected to experimental compression had likewise both bloomed and borne fruit normally.

It is evident, therefore, that the compression which produces very important local modifications has no influence upon the general development of the plant. This result is all the more remarkable since certain ones of the specimens when subjected to compression exhibited very surprising local deformations: thus a root of the *Raphanus raphanistrum*, whose average diameter was 10 mm. is reduced to 2 mm. along a length of 20 mm. by the action of an external tube of glass, and this is by no means an isolated example.

From the anatomical point of view some of the results obtained are as follows: the surface of the bark has a structure which differs greatly according to whether it develops in contact with the glass or in contact with the earth. In the first case, we observe an epidermis having regular iso-diametric cells slightly cutinized and forming only a single layer while a root growing in earth exhibits subero-phellodermic formations with layers of cork arranged in more or less irregularly developed rows. These experimental results may be compared with the phenomena observed in nature in the case of the ivy, for example. The climbing stalk of ivy attached to a support by its "suckers" possesses suber-phellodermic formations in contact with the support, but a simple epidermis upon the side exposed to the air.

Another general modification in compressed specimens is the total or nearly total suppression of the pith, often accompanied by an abundant lignification of the medullary rays. Among those species which normally possess fibres, imprisonment in glass tubes or plates prevents the development of this tissue, no trace of which remains. On the other hand plants having internal fiber continue to differentiate the tissue in the compressed specimens.

Certain general conclusions may be drawn from the ensemble of the results obtained: certain tissues vary with the mechanical conditions in the surrounding medium (such as the nature of medium, external compression); we may call these tissues of adoption. As we have seen these are either tissues of contraction like the epidermis, tissues of support like the fibers and the medullary parenchyma, or else tissues of reserve like the pith.

The other tissues, on the contrary, which may be called *functional* tissues continue to develop in an almost normal manner in almost all cases. Fibers of the wood may be fewer and narrower than in the contrary specimens but they continue to exist and are not modified except in the ensemble. The same thing is true of the liber; thus the internal liber may continue to exist even when the pith which it ordinarily envelops has disappeared.

To sum the matter up, it is possible to reproduce by experiment not only the dissymmetrical structures observed in certain plants, but also the anatomical modifications which result in certain cases from the influence of the milieu. In this manner we may attempt to find the principle by which these phenomena may be explained.

SOYBEAN MEAL FOR CHICKS.

Experiments conducted at the Purdue University Agricultural Experiment Station on the relative value of meat scraps and soybean meal as a supplement to corn for growing chicks showed that the former were somewhat inferior to the latter. The best growth came from an addition of 10 parts of protein from soybean meal. The next best gain came from 10, 15 and 20 parts of protein from the combination of soybean meal and meat scraps.—Abstracted from the *Journal of Agricultural Research*, Jan. 2, 1920.

[1] N. M. Keith, Blood Volume in Wound Shock, *Special Report, No. 26, Med. Res. Committee*, 1919, 36.

[2] Mme. E. Bloch, Concerning the Modifications produced in the Structure of Roots and Stalks by External Compression (in French). C.R.Ac. Fr., vol. 158, 1914, page 1701.

[3] J. Constantin. Influence of the Milieu upon the Root (in French). Ann. d. Sc. Nat. 7th Series, vol. I, 1885; Comparative Study of the Aerial and Subterranean Stalks of the Dicotyledons (in French). Ann. d. Nat., 6th Series, vol. 16, 1883.

Hypersensitizing Commercial Panchromatic Plates*

Effect of Bathing Plates in Alcohol and Ammonia

By Samuel M. Burka, Ph.D.

ORDINARY dry plates, which owe their sensitivity to the silver halides alone, are sensitive only to the violet and blue regions of the spectrum. If, however, a suitable dyestuff be added, the emulsion becomes sensitive to other regions, the particular region depending on the dye used. Thus erythrosin sensitizes to the green and greenish yellow, pinaverdol to the green and yellow, pinacyanol to the orange and red and dicyanin to the extreme red and infra-red.

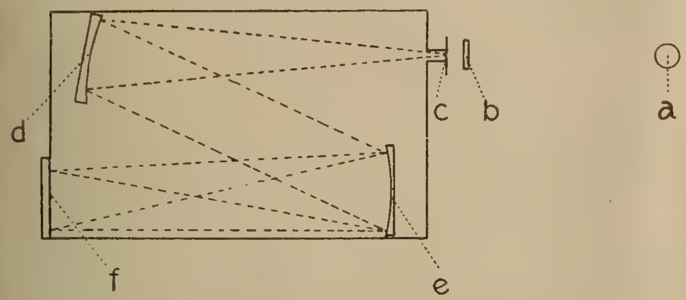


FIG. 1. APPARATUS USED IN THE SPECTOGRAPHIC METHOD OF SENSITOMETRY

a, lamp source; *b*, yellow glass; *c*, slit; *d*, concave mirror; *e*, diffraction grating; *f*, plate to be tested.

The dyestuff is applied to the halides in one of two ways. In the commercial orthochromatic (sensitive to green and yellow) and panchromatic (sensitive to all colors) plates, the dyes are incorporated in the emulsion and the mixture flowed over the glass plate. The second method consists of bathing an ordinary blue-sensitive plate in a dilute solution of the dye and allowing the plate to dry.[1]

The bathed plates are in general faster than the commercial plates[2] and, of course, have the advantage that the plates can be sensitized for any desired region. Certain dyes, moreover (dicyanin, for example), cannot be successfully incorporated in the emulsion. The bathed plates, however, if not used soon after bathing, or if kept at a high temperature, are, in the case of most dyes, more susceptible to chemical fog. Dicyanin and pinacyanol bathed plates when prepared so as to produce the greatest sensitivity are useless after three or four days.

It has long been known that, though at the expense of keeping qualities and freedom from chemical fog, the speed of bathed plates can be increased by the addition of ammonia to the dye-bath. Since this increase is quite marked in the case of some dyes, it was hoped that in this way commercial plates could have their speed increased, and, at the suggestion of Dr. P. W. Merrill, a study was made at the Bureau of Standards of the influence of ammonia on commercial orthochromatic and panchromatic plates.

SENSITOMETRY.

Three methods of sensitometry were used: first, the three-color screen method; second, the spectograph method; and third, the Hurter and Driffield method.

The first method, based on Abney's method,[3] which, however, was used only as a qualitative method at first consists of exposing the plates to a constant light source (usually a nitrogen-filled tungsten lamp corrected by color screens so as to have an energy distribution similar to daylight) behind a so-called trichromatic sensitometer plate. This plate is a neutral screen having four strips of squares of increasing density, each square having twice the density of the preceding. One of these strips is left white, while on the others are placed a red, a green, and a blue filter intended to be of the same luminosity and mutually exclusive. The plates to be tested are thus exposed to varying intensities of white, red, green and blue light.

The second method avoids the difficulty of obtaining filters transmitting pure spectral colors, by exposing the plate in a spectograph.

The apparatus (Fig. 1) consists of a concave grating of 50 cm. radius with 20,000 lines per inch, mounted in parallel light with a 100-watt "daylight" tungsten lamp on 110-volt A. C. circuit as a source. For use with color sensitive plates a piece of yellow glass (7 mm. thick, Corning G 351 CE) barely transmitting the hydrogen blue line with wave-length 4861A was placed in front of the slit to cut out the second order blue. The region photographed was from about 4800A to the limit of sensitivity of the plate. A pair of cross-hairs just in front of the plate at the position of the red line of hydrogen (wave-length 6563A) and of the blue line (4861A) served as reference marks. Fig. 2 gives the energy distribution of the lamp and screen combination. The energy was determined in the spectrophotometric laboratory, visually on a König-Martens Spectrophotometer, by a substitution method of comparison with a radiometrically calibrated Mazda lamp.

The photographic densities were measured on a Hartmann Microphotometer. This method gives immediately the sensitivity of the plate to all parts of the spectrum; but since,

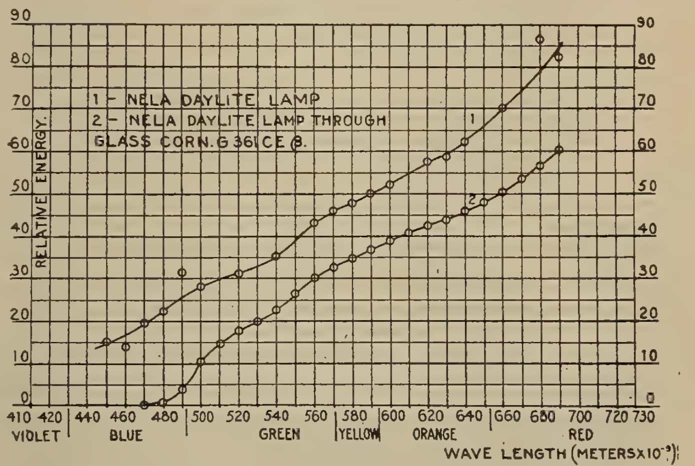


FIG. 2. ENERGY DISTRIBUTION OF THE LAMP AND SCREEN COMBINATION

during the course of the work, minor changes (change of slit, resilvering of mirror, etc.) were made, the exposure times on different sets of plates were not always equivalent.

Furthermore, since the plates were of different kinds and showed markedly different rates of development, they were, in this part of the work, developed by tray until they showed

*Reprinted from, and cuts loaned by, the *Journal of the Franklin Institute*.

[1]Eder, "Handbuch der Photographie," 1902, vol. iii, p. 169 *et seq.* For the Bureau of Standards methods see Bulletin Bureau of Standards, 14, 371, 1917.

[2]Eder, "Handbuch der Photographie," 1902, vol. iii, p. 169. Reference to Schumann, Oct., 1885; Phot. Wochenbl., 1885, p. 395.

[3]*Phot. Jour.*, June, 1895; Eder, "Phot. Korr.," 1903, p. 426. Chapman Jones, *Photo. Jour.*, 1901, 256.

the amount of fog allowable in plates to be used in general photography. The density of the silver deposit obtained depends on the time of development, so that in the curves obtained the shapes (maxima and minima) are the really important parts and the density is only approximately a measure of the speed.

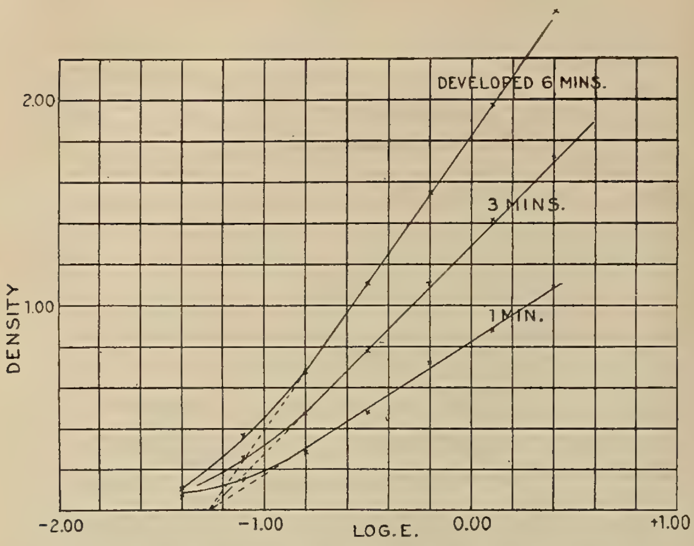


FIG. 3. ILFORD SPECIAL RAPID PANCHROMATIC (5630 N).

Untreated; no filter; speed, 4.45.

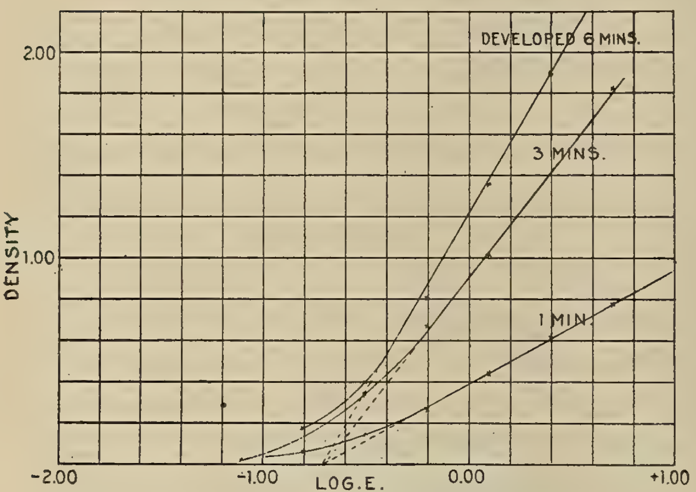


FIG. 4. ILFORD SPECIAL RAPID PANCHROMATIC (5630N).

Treated; no filter; speed, 18.2.

The method generally adopted for the measurement of the speed is that of Hurter and Driffield.[4] Specimens of the plate to be tested are exposed for the same time, behind a sectored wheel, to a standard light source. The transmissions, T, of the images obtained are measured and their densities, defined as — log T, are plotted as ordinates and the logarithm of the time of exposure, E, as abscissas.

The curve so obtained is known as the characteristic curve of the plate. It consists of three parts: the first part is concave upward, the second is a straight line and the third is concave downward. Prolong the straight line part of the curve until it intersects the axis of abscissas. The numerical value of the exposure at the point of intersection is known as the inertia, i, of the plate and the speed is defined as $1/i$. Hurter and Driffield showed that this inertia of a plate is independent of the kind of developer used (except for strong pyro and for the presence of free bromide) and of the time of development (see Figs. 3 and 4). Free bromides, either in the film or in the developer, shift the point of intersection of the straight line portions of the curves to a point below the axis. The plates for which Fig. 5 gives the characteristic curves contain free bromide in the emulsion.

The Hurter and Driffield speeds for several ammoniated and unammoniated plates were obtained, using an apparatus designed and built by Mr. R. Davis of the Bureau of Standards. The light source (a calibrated tungsten lamp) is corrected for daylight, and means are provided for accurately controlling the current through the lamp, the speed of the sectored disk and the total time of exposure.

PROCEDURE.

A series of Cramer Spectrum Process and Ilford Special Rapid Panchromatic plates were bathed for four minutes at 16° to 18° C. in water containing increasing amounts of ammonia, and were then exposed in the spectograph. Both Metol-Hydroquinone and Pyro developers were used. It was soon found that the plates showed fog in development unless they were kept cool while drying and were dried rapidly. The plates showed a progressive increase in speed with increase in ammonia concentration until, with a bath containing 4 c.c. of ammonia water (containing 20 per cent NH_3) in 100 c.c. distilled water, the plates began to fog so badly in development as to be useless.

The ammonia was then added to water-alcohol mixtures of varying concentrations. The plates bathed in the alcoholic ammonia did not have their sensitivity increased as much

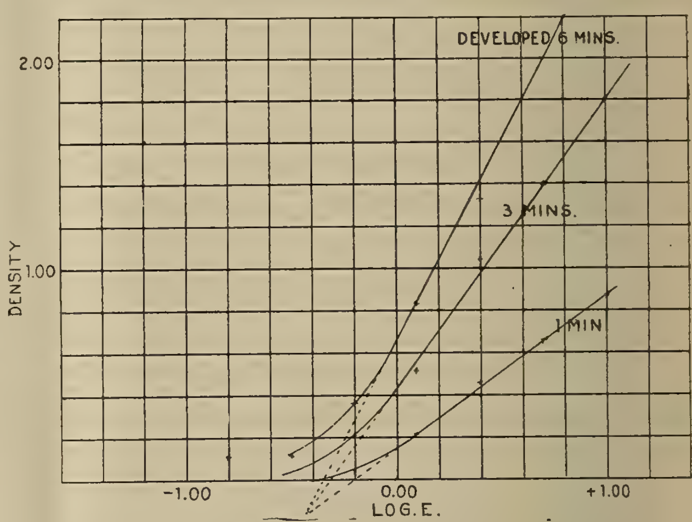


FIG. 5. CRAMER SPECTRUM PROCESS (1439).

Treated; Wratten "F" filter; speed, 1.88.

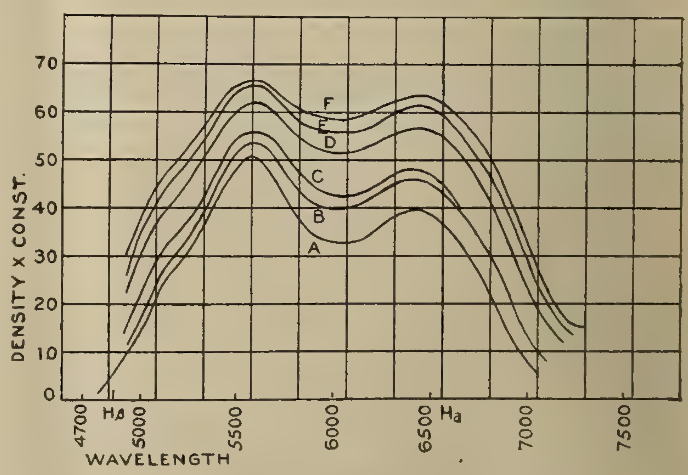


FIG. 6. CRAMER SPECTRUM PROCESS (1439).

A, untreated; B, 1/40 c.c. ammonia; C, 1/10 c. c. ammonia; D, ½ c.c. ammonia; E, 1 c.c. ammonia; F, 3 c.c. ammonia; 75 c.c. water; 25 c.c. alcohol. Same exposure and development.

[4]Hurter and Driffield, *Jour. Soc. Chem. Industry,* May, 1890, p. 455.

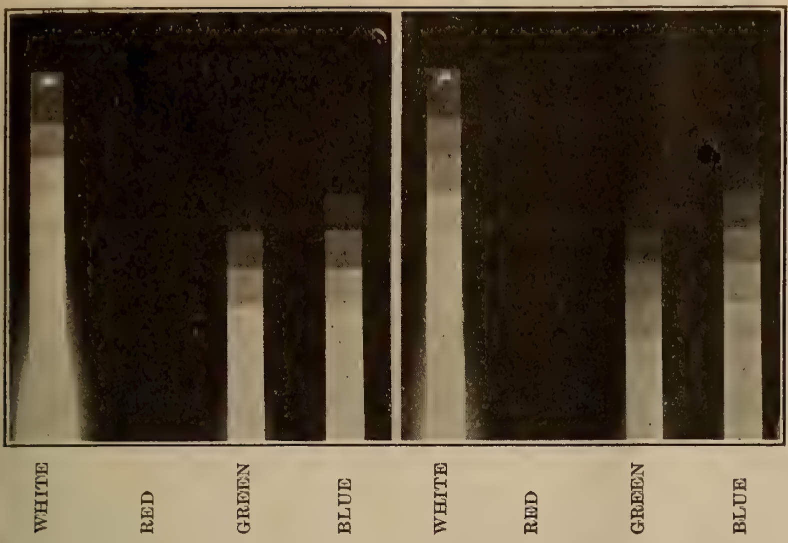


FIG. 7. CRAMER COMMERCIAL ISONON

as in the corresponding water baths, but were very much cleaner working. Seventy-five parts of water to twenty-five of ethyl-alcohol gave the best results, and this proportion was adhered to thereafter. Sometimes the plates showed a slight network of fog (mottling) similar to the drying marks shown when plates are dipped (not soaked) in alcohol to hasten drying. Washing in 95 per cent alcohol for 20 or 30 seconds after the ammonia bath prevented this, but this final wash is not usually necessary, especially if the plates are not forced in development.

Fig. 6 gives the spectral sensitivity curves of a series of Cramer Spectrum Process plates in baths containing 1/40, 1/10, ½, 1 and 3 c.c. of 20 per cent NH_3 ammonia water to an alcohol-water mixture of 25 parts of alcohol and 75 parts of water.

Three to 3½ c.c. of the strong ammonia to 75 c.c. of water and 25 c.c. of alcohol was adopted as the combination to be used, and except for a few trials on various plates, the plates were all treated with this same mixture.

The time of bathing, 2, 4, or 6 minutes, had no appreciable effect, provided that the film was bathed long enough to get thoroughly soaked. Four minutes was the time used for bathing in all subsequent experiments.

For a study of the keeping qualities of the plates, a number of Cramer Spectrum Process and Ilford Panchromatic plates were treated and samples of the treated plates exposed and developed after being stored for various lengths of time. The Cramer plates showed deterioration after a week but were still usable. The Ilford plates were useless after three or four days. The plates which were bathed without the use of alcohol deteriorated more quickly.

The bath of 3 to 3½ c.c. of ammonia water (20 per cent NH_3), 25 c.c. of alcohol and 75 c.c. of water is recommended. Three and one-half c.c. of ammonia water to 100 c.c. of water is used where the maximum increase of sensitivity is desired, but the plates are much more susceptible to fog in development and must be used within a few hours of drying. Development should be carried out, using the Wratten Safelight No. 3 and over-development carefully guarded against.

ORDINARY PLATES.

As is well known, the speed of the silver halide emulsion can be increased by treatment before it is flowed on the plate. This treatment, known as "ripening," is usually either to keep the emulsion at a high temperature for some time or to add ammonia. This ripening by ammonia is effective even after the plates are ready for use.[5]

On ripened plates such as the Seed 30 and Central Special, and on the Seed 23, there is no appreciable increase in speed when they are bathed in ammonia. In some cases there is rather a slight decrease in speed. On one plate known to have been ripened by the ammonia process before coating (Central Dry Plate Co.)

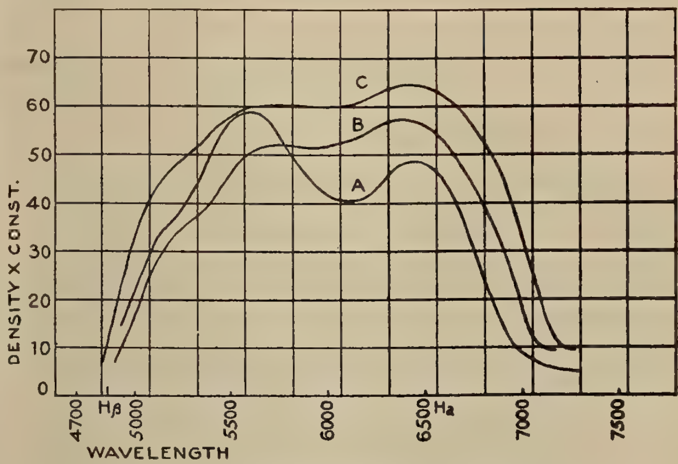


FIG. 9. CRAMER SPECTRUM PROCESS (1439).

A, untreated, 10-second exposure; *B*, treated, 5-second exposure; *C*, treated, 10-second exposure.

which, however, was not fresh, this increase in speed on subsequent bathing in ammonia was quite apparent.

Microscopic examination of the treated and untreated plates showed no difference in the size of the grain.

ORTHOCHROMATIC PLATES.

A number of plates sensitive to the green and yellow were tried. Most of them showed no appreciable change in sensitivity. Some had the sensitivity decreased, *e. g.*, Cramer Commercial Isonon. The sensitivity of the Seed Aero Ortho was increased slightly.

Fig. 7 is a print from treated and untreated Cramer Commercial Isonon negatives obtained through the tricolor hensitometer plate. It will be noted that the change in sensitivity can be observed in all the strips.

The Cramer "Trichromatic" showed an increase in sensitivity comparable to that observed in the Spectrum Process.

Treatment of Eastman and of Ansco N. C. films, which are orthochromatic, showed no change

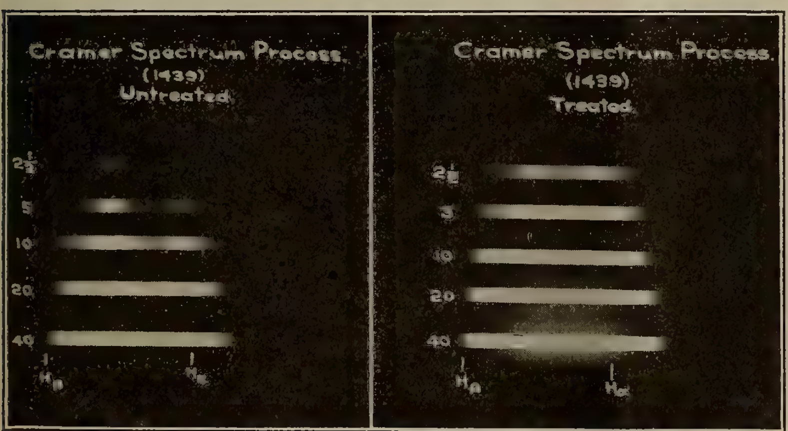


FIG. 8. CRAMER SPECTRUM PROCESS (PANCHROMATIC).

[5] Eder, "Handbuch," iii, p. 63.

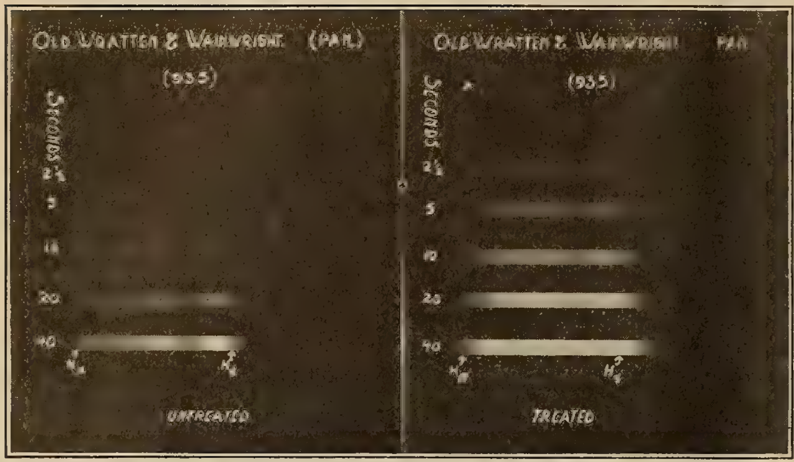


FIG. 10. WRATTEN & WAINWRIGHT PANCHROMATIC.
Expiration date, September 15, 1915. Used Oct. 21, 1918.

larger than the differences that are attributable to experimental errors.

PANCHROMATIC PLATES.

Every panchromatic plate tried showed remarkable increase in speed. The very fast plates, several of which were developed only recently in response to the need for fast color sensitive plates for aerial photography, showed a somewhat smaller increase than the slower and process plates.

This sensitometer plate method gives the relative speeds of plates towards filters, but since the filters do not transmit pure spectral colors (the blue transmits a band in the red and the transmission of the three filters overlap) more can be learned of the color sensitivity from the spectrograph curves.

Fig. 8, a print from a treated and an untreated Spectrum Process Plate, shows the sensitivity of the plate to each wavelength.

Fig. 9 gives the spectral sensitivity curves obtained with the Spectrum Process plate; 5- and 10-second exposures on the treated and 10 seconds' exposure on the untreated plate.

One of the most striking changes produced by the ammonia treatment was the action on old panchromatic plates. A Wratten and Wainwright plate marked "use before September 15, 1915," was exposed on October 21, 1918, in the spectrograph. As was to be expected, the plate was badly fogged on the edges and the sensitivity of the emulsion was much below that of a fresh plate. Treatment with ammonia brought the sensitivity up to an even greater value than that possessed by a fresh plate (see Fig. 10).

The Hurter and Driffield curves for some of these plates gave the following values for the speed:

	Untreated	Treated
	White Light	
Cramer Spectrum Process (1439)	10.2	25.1
Eastman Experimental Panchromatic IV d	12.6	17.7
Ilford Special Rapid Panchromatic 5630 N	4.45	18.2
Standard Orthonon	23	
	Minus Blue Filter	
Eastman Experimental Panchromatic 2199	1.91	4.37
Ilford Special Rapid Panchromatic 56,416	4.37	13.5
	F. Filter	
Cramer Spectrum Process (1439)	0.49	1.88
Eastman Experimental Panchromatic IV d	0.57	2.18

The figures give the absolute speeds of the plates to white light and through the Wratten Minus Blue and F Filters on the Hurter and Driffield scale. The value for the speed of the Standard Orthonon plate to white light obtained on the same apparatus is given for comparison. The Minus Blue, a deep yellow filter, cuts out all the blue and violet light, while the F, a deep red, transmits only the long red wave-lengths.

These figures show the remarkable increase in speed of the plates, particularly in the long wavelength region. Thus the Cramer Spectrum Process plates are increased in speed 150 per cent to white light and nearly 400 per cent to the red. Through the Minus Blue filter one of the Ilford plates is increased 300 per cent.

These plates were used in experiments in airplane photography, where for photographing through the haze a fast red-sensitive plate is necessary. Figs. 11 to 13 are a set of prints from the Ilford plates. Figs. 11 and 12 were printed for the same time from the untreated and treated plates. Fig. 13 is from the untreated negative timed to give the best print. The negatives were given the same exposure in the air and were exposed within a few seconds of each other through the Minus Blue filter.

The increased speed of the treated plate is apparent. It will be seen, also, that the treated plate is less contrasty and givs much better detail in the shadows.

Fig. 14 is from a Seed 30 plate used with no filter at an altitude of 17,000 feet on a slightly hazy day. Fig. 17 shows the same scene taken on a treated Spectrum Process plate through the A filter. The pictures were taken simultaneously in a multiple lens camera. The increased haze penetration obtainable by the use of the red filter is clearly shown.

ACTION ON MINIMA.

On every plate which had an irregular curve of spectral sensitivity, the minima were raised and in many cases smoothed out entirely. For example, note the minima at 6100A in Fig. 9.

This property of the ammonia treatment adds greatly to the value of the plates in the photography of spectra, especially as the sensitivity is extended some 200 Angström units further into the red at the same time. The bad effect of a minimum is, however, smoothed out to some extent in ordinary photography through filters.

PLATES WITH KNOWN DYESTUFFS.

The difference in behavior between the ordinary and orthochromatic plates and the panchromatic plates shows clearly

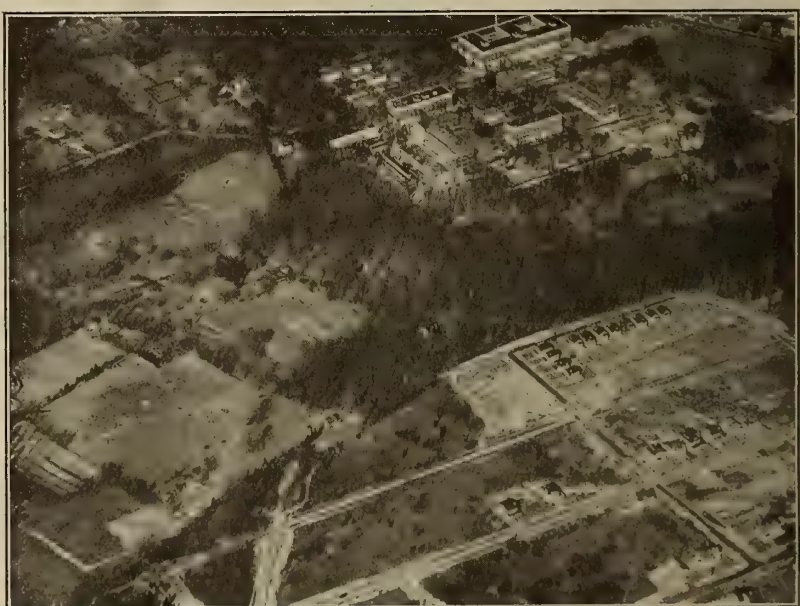


FIG. 11. AMMONIATED PLATE. PRINTED 21 SECONDS.
Hypersensitized Ilford plate. 1/130 second exposure. Minus blue filter. Oblique from 4,000 feet.

that the sensitivity increase dealt with here is not that observed by Eder, which is due to "ripening," but is an action associated with the dyestuff.

The effect of the ammonia is to increase the sensitivity of the emulsion to the incident light and not to increase the developability of a latent image already formed, since a plate treated with ammonia after exposure but before development showed no increase in sensitivity. That the action is not due to the alkalinity of the bath is shown by the fact that bathing in a solution of sodium hydroxide having the same concentration of OH ions had no effect on the speed of the plate.

Part of the increase in speed is, probably, due to the fact that some of the dyestuff in the gelatine film is washed out and its screening effect diminished. The ammonia bath becomes colored with use and a color difference is observed between the untreated and treated plate before development.

The pinaverdol dyes sensitize for the green and yellow and an orthochromatic plate containing one of this series of dyes has the sensitivity increased by the ammonia treatment. Fig. 15 is a plate made up by the Cramer Dry Plate Co., using pinaverdol Pv. I., made by the Bureau of Chemistry, and marked by Cramer "similar to Trichromatic." The Trichromatic plate has the sensitivity curve of a pinaverdol dyed plate and Fig. 16 gives the curve before and after ammonia treatment.

FIG. 12. UNTREATED PLATE. PRINTED 21 SECONDS

Ilford panchromatic plate. 1/130 second exposure. Minus blue filter. Oblique from 4,000 feet.

Mixtures of pinaverdol and pinacyanol are the dyes usually used in the preparation of panchromatic plates intended for spectrum photography. The mixture of these two dyes alone leaves a strong minimum at about 6100A. The ammonia treatment smooths out the minimum. In many plates intended for general photography other dyes are added to sensitize in this region.

Fig. 18 gives curves for a plate (similar to their Spectrum Plate) made up by the Cramer Co., using a mixture of the Bureau of Chemistry's pinacyanol, Pc. XII., and pinaverdol, Pv. I. It will be noted that the addition of pinacyanol lowers the maximum due to the pinaverdol.

The dyes used in sensitizing are nearly all basic dyes, and it is not probable that the ammonia changes the dye itself. On the addition of ammonia to the dye solution before bathing, there is no color change. It is possible that the solvent action of the ammonia on the silver halide facilitates the reaction between the dyestuff and the silver salt, in addition to its softening effect on the gelatin. This, however, does not account for the raising of the minima. It is possible that there is the formation of a $AgNH_3Cl+$Dyestuff molecule with a photosensitiveness slightly different from that of the original molecule.

FIG. 13. UNTREATED PLATE. PRINTED 8 SECONDS

Ilford panchromatic plate. 1/130 second exposure. Minus blue filter. Oblique from 4,000 feet.

SUMMARY.

Since ammonia, when added to the dye bath in preparing bathed plates, increases the sensitizing action of the dye, its action on commercial plates was investigated.

In the course of the work three methods of sensitometry were used. Of these, one was used as a first qualitative test; the second, the spectrograph method, was used to study the effect of the ammonia on the sensitivity of the plate to each wave-length; the third, the Hurter and Driffield method, gives the absolute value of the speed of the plate.

It was found that by bathing commercial panchromatic plates in a solution of 25 cubic centimeters of ethyl-alcohol, 75 cubic centimeters of water, and 3 cubic centimeters of strong ammonia water (20 per cent NH_3) for four minutes at 18 degree centigrade and drying rapidly, the speed to white light is increased 100 per cent in nearly all cases, and the sensitivity in the red portion of the spectrum is extended one hundred or more Angström units. The speed in the red portion of the spectrum is increased, in many cases, 400 per cent. If the plates be bathed without the alcohol (100 c.c. water, 3½ cubic centimeters of ammonia water) the speed is still more increased, but the plates should be used immediately after drying.

Ordinary plates do not have their sensitivity appreciably changed. Most brands of orthochromatic plates are not improved, although one, the Cramer Trichromatic, showed the same increase as the panchomatic plate.

My thanks are due to Dr. J. S. Ames for his supervision of the present investigation and for valuable advice which he rendered during many conferences.

The energy distribution of the light source in the spectrograph was determined by Mr. E. P. T. Tyndall and Mr. H. J. McNicholas of the spectrophotometric laboratory. I am also indebted to

FIG. 14. SEED 30 PLATE, F/11. NO FILTER

30° oblique from 17,000 feet. Hazy day. 1/100 second exposure. Taken simultaneously with Fig. 17 in a multiple lens camera.

Mr. R. Davis and Mr. F. M. Walters, Jr., through whose help the Hurter and Driffield curves were obtained, and to Dr. C. C. Kiess, under whose direction and coöperation most of the work was done.

THE ORIGIN OF OCEANS AND THE ARCHITECTURE OF THE EARTH.

AT a meeting of the Oceanographic Institute, held Dec. 6, 1919, a novel, attractive and interesting theory of the formation of oceans was expounded by M. Belot. The hypothesis is of especial interest since it undertakes to explain not merely ocean formation but also the peculiarities of the architecture of the earth. M. Belot has subjected known data to calculation and has deduced logical conclusions, taking as his starting point the following hypothesis: The earth at the moment when it was in one of the first stages of the condensation of its nebulous matter, *i. e.* while it was a fluid, incandescent, anhydrous, spherical nucleus, was animated by two movements: namely, the rotation around the line of its present poles and the other the movement of translation from south to north along the line of these poles. These two movements exist at the present time—consequently the hypothesis is entirely admissible. Furthermore, there is no other hypothesis, whether astronomical or geological, which when subjected to test by calculation and observation permits the explanation of all the facts, both present and ancient. We may mention in particular that the theory of present causes, which is accepted as a dogma in geology and as the very foundation of this science, is absolutely powerless to explain all the said facts.

If we accept the theory formulated by M. Belot, events must have occurred in the following manner:

When the anhydrous nucleus, surrounded by an atmosphere which exerted upon it a pressure approximately equal to 360 of our present atmosphere had radiated sufficient heat into interstellar space to reduce its temperature to somewhat above 1,300° C. water was able to form, but must have been still in the state of vapor, since the aforesaid temperature is that of the dissociation of the elements of water and is much greater than its critical temperature 365° C. (the critical pressure of water being 194 atmospheres). When the temperature had fallen to 1,100° C. the materials which were destined to form the solid crust of the terrestrial globe solidified around the austral pole, forming a cap along whose edge detached blocks appeared, which, floating upon the surface of the liquid nucleus, finally detached themselves to the mass surrounding the boreal pole, thus constituting the foundation of the continental masses now existing in the northern hemisphere. Then, as the cooling process continued, the solid mass if the austral pole extended towards the north and joined the boreal mass. Thus was formed the crust of the earth.

At a temperature of from 800° to 700° C. the haloid salts, which had previously existed in the atmosphere in a state of vapor, fell in the form of rain upon the austral cap, there forming masses of considerable extent which would represent at the present time a uniform thickness of 45 m. over the surface of the globe.

When the temperature had fallen to 365° C., *i. e.* the critical temperature of water, the latter became able to exist in the liquid state and was precipitated in the form of rain almost instantaneously upon the austral "cap" of the earth. Like the masses of matter which had been previously solidified or precipitated this water was transported from the south to the north, and far more easily than the materials forming the

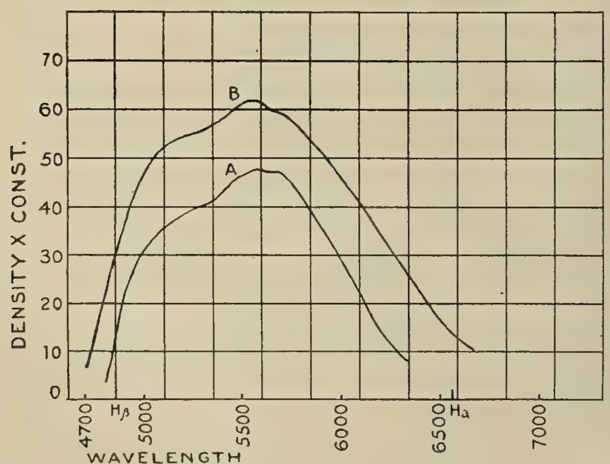


FIG. 15. G D IV. PvI (similar to trichromatic)

A, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

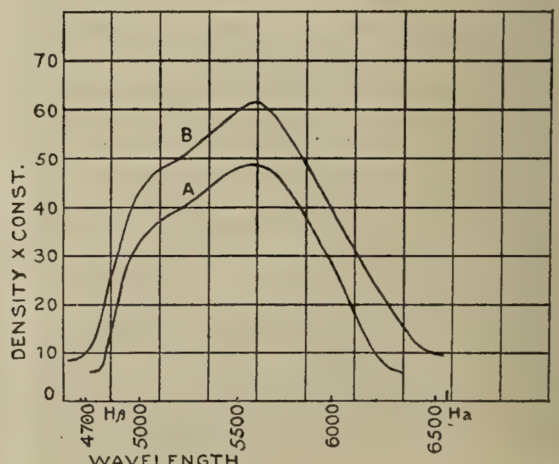


FIG. 16. CRAMER TRICHROMATIC, NO. 21

A, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

crust of the earth by reason of its fluidity; in its passage toward the north it carried with it to begin with the haloid salts and then sheared off the surface of the austral continent for the benefit of the boreal continents. This action must have exhibited extraordinary intensity by reason of the great rapidity at which the water traveled as well as of its high temperature and of the enormous pressure which it exerted upon the bottom of the ocean, since this first austral deluge represents a layer of water covering the entire surface of our present globe to a depth of 1600 m.

When the temperature of the atmosphere, continuing to decrease, had fallen to 1,100° C. the austral pole was the seat of a second deluge, even more abundant than the first (representing a depth of water of 2,000 m.), but less erosive in character. The solid austral masses of matter were nevertheless again sheared off and the material transported towards the north, being deposited upon the foundation previously laid down and forming marine deposits which gave to the continents the broad outlines they have at present, *i. e.* the roughly triangular form pointing toward the south which they all possess, and thus modelling the terrestrial surface in almost the shape it presents at present, with a predominance of masses of earth in the northern hemisphere and of oceans in the southern hemisphere.

FIG. 17. HYPERSENSITIZED CRAMER SPECTRUM PROCESS PLATE. F 4.5. WRATTEN "A" FILTER

30° oblique from 17,000 feet. Hazy day. 1/100 second exposure. Taken simultaneously with Fig. 14 in a multiple lens camera.

It was in this manner that the oceans were formed and it is evident that they were hot in the beginning and hat they have always been salty, in fact more salty, at first, than they are at the present time, since they were then fully saturated with mineral salts, as is indeed the constituent water of all rocks, since this constituent water is fossil sea water.

The austral continent, whose importance has been proved by the recent expeditions to the south pole, is merely the remainder—as we may say the non "decapitated" remainder of a continent which was originally 33 times as extensive as at the present time; the rest of the material originally composing it has served to form the boreal continents and the deposits which lie beneath the deep seas.

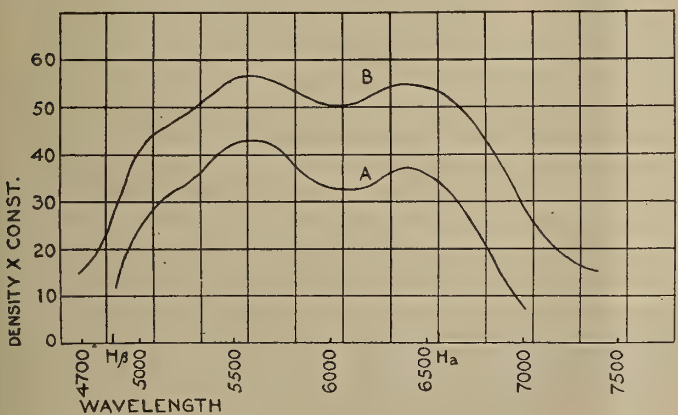


FIG. 18. G D III. PcXII and PvI

A, untreated, 10 seconds exposure; *B*, treated, 10 seconds exposure.

All known facts that are of primary importance or merely accessory, as well as all the most recent discoveries in geography and in chemistry and the physics of the globe, confirm this theory of austral deluges formulated by M. Belot. Some of these may be mentioned here.

The great ocean depths have always existed, and existed in the very localities where they are now found; the existence of a sea surrounding the north pole is explained by the formation of a depression around the north pole at the time of the first solidification of the crust of the earth.. The dense red clay found at great depths has never left these ocean depths and has never taken part in the formation of the sedimentary strata of the continents of the northern hemisphere. This clay is highly ferruginius in character and its presence explains the recently discovered effect which these great ocean depths of the austral continents exert upon the magnetic needle.

The theory of austral floods also explains the method in which radio-active elements are distributed in the sub-soil and the formation of the deposits of metallic ores and veins of metal and metamorphic rocks. These great austral floods which no human eye has ever seen, these great movements, have nothing in common with the flood described in the Bible, nor with the fluctuations of the sea which have modeled the surface of the earth at different geological periods. The latter are movements of great insignificance compared with those first translations of matter described above, and their effects have been almost entirely confined to the northern hemisphere.

MAGNETIC AND MECHANICAL TESTING OF IRON.

MAGNETIC tests have been limited hitherto to magnetic purposes, but attempts have recently been made to substitute such tests in place of mechanical tests for determining the physical properties of the ferrous group of metals.

Magnetic tests, however, require exact laboratory work, not always applicable to workshop conditions and the vague nomenclature in vogue does not facilitate their study.

The question, therefore, arises: are the magnetic properties of commercial iron sufficiently uniform and, in their interpretation, sufficiently definite, to reveal mechanical defects in the metal by irregularities in the magnetic tests. The evidence so far is promising, if not conclusive.

The simplest way of magnetic measurement of rails is the ring method. A ring is wound with the magnetizing primary, over which is placed a few turns of the secondary winding, in circuit with a d'Arsonval galvanometer. In the testing of ball-bearing races, ritary hysteresis measurements have been substituted for the throw of a ballistic galvanometer.—Abstracted from *Engineering* by *The Technical Review.*

Science and National Progress

Edited by a Committee of the National Research Council

Dr. Vernon Kellogg, Chairman, Dr. R. M. Yerkes, H. E. Howe

PRACTICAL MENTAL MEASUREMENT.

Intelligence Tests for Elementary Schools.

By Robert M. Yerkes,
Chairman of the Research Information Service of the National Research Council,
Washington, D. C.

The National Research Council is a co-operative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

THE purpose of this article is to announce methods of group intelligence examining which have been prepared under the auspices of the National Research Council for use in our elementary schools, and particularly in grades three to eight. These methods are practically completed and arrangements have been made with the World Book Company of Yonkers, New York, for the manufacture and distribution of all materials necessary for the conduct of examination.

Fortunately the essential materials are extremely simple, consisting merely of the record blank, a printed key for the scoring of the papers, and a little book which gives full directions for the conduct of the examination and use of results. It is expected that the "National Intelligence Tests," as these examinations are to be called, will be published during the spring of 1920.

In order that these methods may be self-improving, it has been arranged between the National Research Council and the World Book Company that the ordinary commercial profits on the publications shall be used for the expense of research on methods of psychological examining and their useful applications.

Oddly enough man has given vastly more attention to the control of inanimate nature and of the lives of other living things than to that of his own behavior. Largely because of the lesson of the war, this situation seems likely to change rapidly and radically. For among other things the great conflict emphasized in an unusual manner the importance of definite knowledge of human traits and of ways of utilizing them to advantage. It became clear to thousands of men and women who had to deal with military problems that the practical classification of men by various sorts of physical and mental measurement is essential to the achievement of efficient work.

Although it has long been recognized that physical characteristics must be considered in connection with occupational choice and the kind and amount of work which may reasonably be expected of a man, it is largely because of our war-time experiences that we have come to recognize widely the similar importance of considering mental qualities and capacities in their relations to vocation and to the varied social demands.

Man's mental constitution is just as complex as his physical body and as highly variable. But fortunately it is possible for us to measure certain at least of the important traits or qualities of mind almost as readily as we measure height, weight, muscular strength, endurance, and numerous other physical characteristics. It is not a simple task to prepare a practically useful description of the mental make-up of a human being for there are many important traits or aspects of mind which are significant and must be measured. It is common to think and speak of mind as consisting of intelligence, feeling, and will, but even if these terms are made to include all aspects of mind each designates a complex group of facts and further analysis is necessary.

Most of the mental measurements which are being made for practical purposes in our schools, hospitals, prisons, reformatories, factories, and in our army and navy, are really measurements of one or another sort of intellectual processes, such, for example, as memory, constructive imagination, the ability to think simply or to reason. But quite inseparable from what are properly called intellectual processes are other processes which are usually termed feelings or emotions. These chiefly determine the temperament and possibly also the character of the individual, and so it happens that even although a person may be intellectually able and competent for a certain sort of task he may be quite unfit for the task because of emotional or, better still, temperamental characteristics.

The accompanying figure (1) indicates certain differences in the intelligence of two individuals. X was a sergeant in the United States infantry, thirty years old, a teamster who had progressed in school as far as the fourth grade, and before entering the army received $18 a week wages. Y was a private in the infantry, twenty-three years old, a tool dresser by trade, with eighth grade education, and received before entering the army $49 per week. The figure shows how strikingly these two men differ with respect to eight groups of intellectual measurements.

Fig. 2 similarly indicates the differences for eight mental tests among three groups of army officers, namely: medical officers, chaplains, and engineers. These differences are in many respects surprising and make one wonder whether they are inborn or the result of education and professional experience. They may possess major vocational significance.

A really useful description of the mental make-up of any person must rest, then, upon measurements of many mental traits. This is just as true for the practical applications of psychology as for disinterested research. A man may have intelligence enough to succeed as a carpenter but he may lack the desirable sorts of mechanical skill and it may be extremely difficult or impossible for him to acquire them. An army officer may be highly intelligent and eager to lead but because of deficiency in the combination of emotional, volitional, and intellectual traits which determine leadership, he may be wholly unsuccessful in his profession. Again, the salesman may fall short of the requirements of his occupation because of temperamental characteristics or because of inadequate intelligence.

It is now many years since Alfred Binet in Paris demonstrated, by the use of very crude methods, the possibility of classifying children with respect to mental make-up so that educational work might be facilitated and the individual child given better opportunity for development. The influence of Binet's work has been world-wide. It has stimulated alike endless improvements in methods of mental measurement and practical applications of the results which these methods made available. The war supplied an opportunity for a convincing demonstration of the importance of psychology in daily life and the preparedness of the profession to be useful. There were few if any greater surprises in the war than this exhibition of the practical value of psychological

methods. Almost over night there developed in America the conviction that psychology can be made serviceable, not only in education as heretofore, but similarly in all of the professions and even in the industries. It has been said by those who should know that the suggestion of the academic, abstract, and impractical given by the word psychology very nearly rendered impossible the introduction of methods of

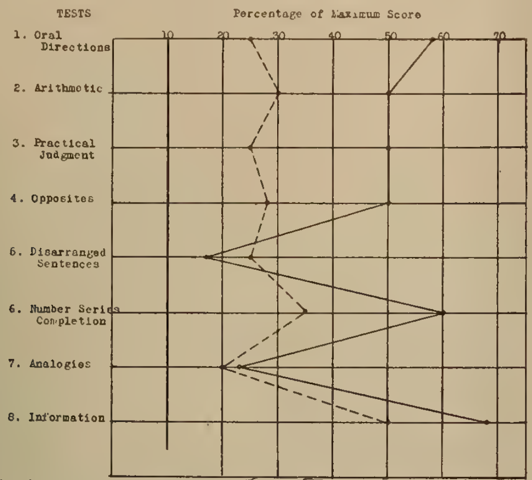


FIG. 1. THIS REPRESENTS THE MEASUREMENTS OF INTELLIGENCE FOR TWO SOLDIERS, X (———) AND Y (- - - -)

mental measurement and classification in the United States Army. It is the more surprising, therefore, that today psychology should be a word to conjure with in the military service. Yet, this is undoubtedly true, and that not because of political influence or of over-suggestibility, but because of the demonstration from day to day, in scores of training centers and in thousands of military organizations, of the ability of the psychological examiner, by means of his almost ridiculously simple methods, to classify men according to intelligence as very superior, superior, high average, average, low average, inferior, and very inferior. For convenience these

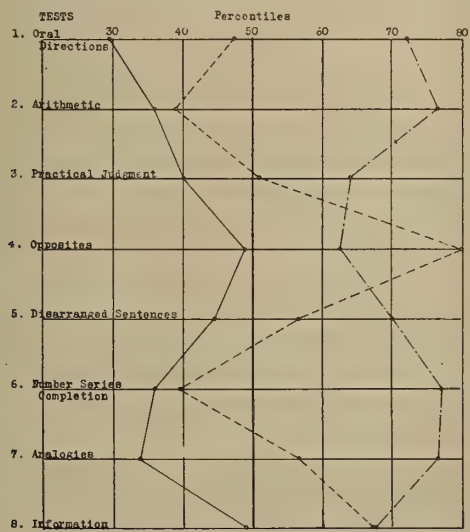


FIG. 2. DIFFERENCES IN THE INTELLECTUAL MAKE-UP OF THREE GROUPS OF ARMY OFFICERS: MEDICAL OFFICERS (———), CHAPLAINS (- - - -), AND ENGINEERS (—.—.—), AS INDICATED BY THE EIGHT TESTS OF THE ARMY GROUP EXAMINATION ALPHA

several groups were usually designated in the army by the letters A, B, C+, C, C—, D, and D—.

Another reason for the amazing success of psychological work in the army was the wholesale demonstration of the fact of marked differences in intelligence among individuals. Although this has long been known to psychologists and to others who have given any considerable amount of attention to the observation of mental traits, people in general had not thought enough on the matter to have any opinion. Army psychologists suddenly supplied the necessary data to create an opinion.

Such charts as those reproduced in Figures 3 and 4 fairly indicate the degree of intellectual difference among important army groups. Almost everyone grossly overestimates the average intelligence of human beings, and similarly underestimates the range of difference in intelligence. Compare, for example, the distribution of intelligence among the several letter-grade groups A to D— of the enlisted men in the United States Army who could read and write English fairly well, as represented by the heavy solid line of the figure, with the distribution of commissioned officers of the army, represented by the light solid line. Whereas enlisted men occur in considerable numbers in all grades of intelligence from the highest to the lowest, but most frequently in the average of C grade, officers are mostly of either A or B, that is, very superior or superior intelligence. A few are found to fall in the C or C+

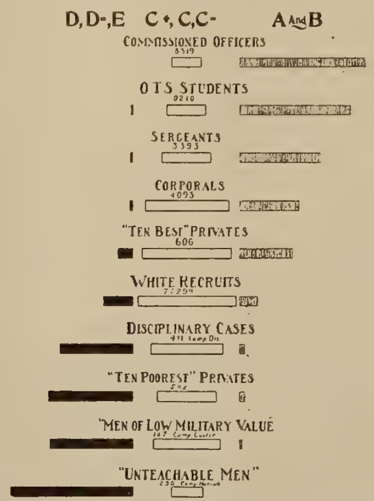


FIG. 3. THE DISTRIBUTION OF INTELLIGENCE GRADES FOR SEVERAL IMPORTANT ARMY GROUPS

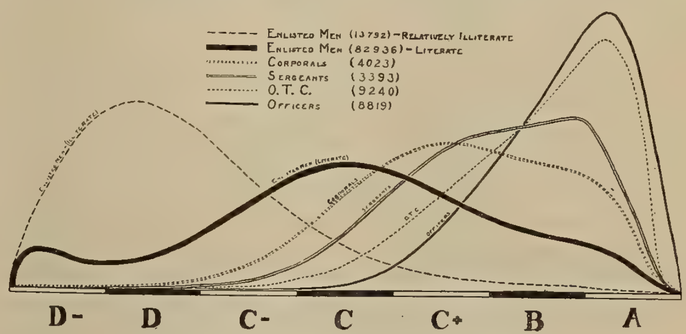


FIG. 4. THE PROPORTIONS OF LOW, AVERAGE, AND HIGH GRADE MEN IN TYPICAL ARMY GROUPS

groups, but there is none in the D group and only an occasional unsuccessful individual in the C— category.

A still more impressive exhibit of difference in intelligence among army groups, and of the practical significance and relationships of intelligence, is supplied by Fig. 4. For simplicity of representation the several grades or levels of intelligence in this chart are arranged in three groups which may be designated as high, medium, and low. Low intelligence is always represented in the figure by the solid black bar, medium intelligence by the white bar, and high intelligence by the shaded bar. It is noteworthy that commissioned officers are all found in the medium or high intelligence groups, while by contrast men designated by their officers as utterly unteachable fall without exception either in the low or the medium intelligence groups. The contrast between the intelligence of the ten best privates and the ten poorest privates, as selected by company commanders, also is worth noting; and the acute reader will not overlook the practical importance of the fact presented by this figure that disciplinary

cases in the army are usually of low grade or medium intelligence and very seldom of high intelligence. It is a natural inference from this figure that had the army rejected the ten per cent of recruits with lowest intelligence, the last four groups of Fig. 4, namely, those designated as disciplinary cases, poorest privates, men of low military value, and unteachable men, would have been reduced so considerably—probably as much as fifty per cent—that army costs and efficiency of training would undoubtedly have been effected to the extent of millions of dollars.

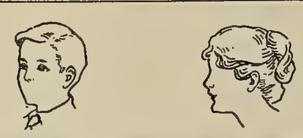
The press early in the development of military psychology seized upon the methods and results of psychological examining as items of news which would appeal to the public. This proved to be true and psychology owes to the magazines and newspapers of the country a degree and quality of publicity which has multiplied many fold both the interest in psychology as science and as technology and the demand for its useful applications. This demand grew so rapidly during the war that the Division of Psychology of the Surgeon General's Office was much embarrassed by the requests from industrial concerns, educational institutions of all sorts, and individuals for the army methods or their equivalents. Similar demands overwhelmed the Committee on Classification of Personnel of the Army, which was engaged primarily in occupational classification and trades testing. At the moment it was impossible to respond satisfactorily to these demands, however reasonable or urgent they might appear. But with the cessation of hostilities the psychologists of the country hastened to show their good will and their eagerness to be of service in non-military ways.

There was organized for the intelligent, systematic study of psychological and other personnel problems in industry The Scott Company, with offices in Philadelphia and Chicago. There were promptly developed methods of examining college students or other groups of mature individuals. Indeed, for this purpose the army method of examining men by groups, which is usually spoken of as 'army alpha,' and which consists of eight different tests of intelligence, has been used for the classification of students in upward of fifty colleges and normal schools. Otis, Thorndike, and Thurston, within a few months of the signing of the armistice, made available group methods of measuring intelligence which are primarily useful in institutions of higher learning. But it remained to provide methods suitable for the classification of children in our public schools.

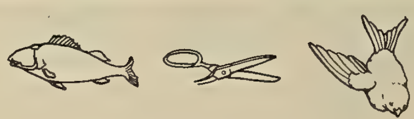
There had been abundant indication of the interest of public school authorities in the army methods and of their desire to secure equally serviceable methods for school use. The need was clearly urgent. Consequently the writer, in coöperation with Lewis M. Terman, presented the matter to the General Education Board of the Rockefeller Foundation, with the suggestion that the preparation of methods of psychological examination suitable for use in grammar schools might be financed by the Board. This suggestion was favorably received and arrangements were subsequently made by which the National Research Council, with the assistance of an appropriation of $25,000, should direct the preparation of methods. In the spring of 1919 a committee consisting of Dr. M. E. Haggerty, Dr. L. M. Terman, Dr. E. L. Thorndike, Dr. G. M. Whipple, and Dr. R. M. Yerkes, was organized by the Research Council to undertake this work. This committee acted promptly and energetically. It systematically surveyed the tests which were available for use and from among them selected something more than twenty kinds for preliminary trial. Many different forms of each of these twenty tests were prepared at considerable labor and expense. Some idea of the nature and variety of these tests is given by the following reproductions of the introductory exercises which were used. Thus, Test 1, as it appears, demands the completion of certain pictures. It should be emphasized that these figures are not complete tests but merely odd samples to indicate the nature of the tests. Test 2 demands the numbering of the pictures in logical order, so that they shall tell a story or indicate the

N V A

TEST 1

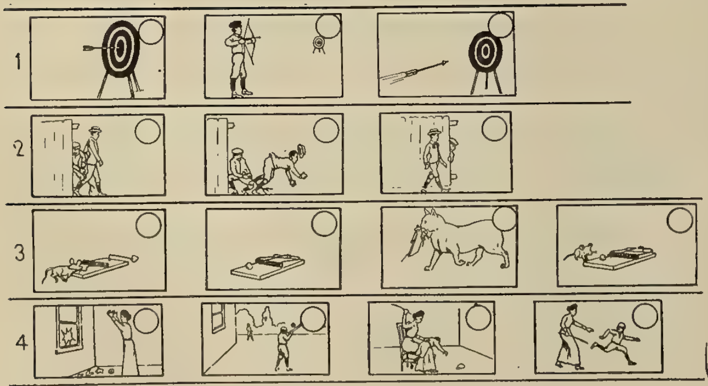


Look at each picture and draw in the part that is left out. Don't try to make it pretty. Make just enough marks to show that you know what is left out. If the drawing is too hard you may write one or more words to show what is left out.



N V B

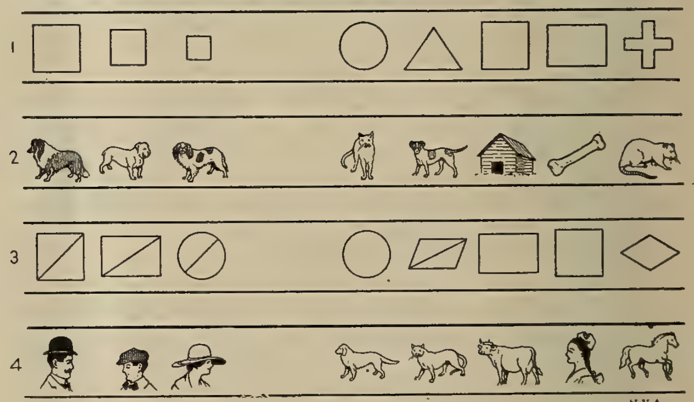
TEST 2



N V B

TEST 3

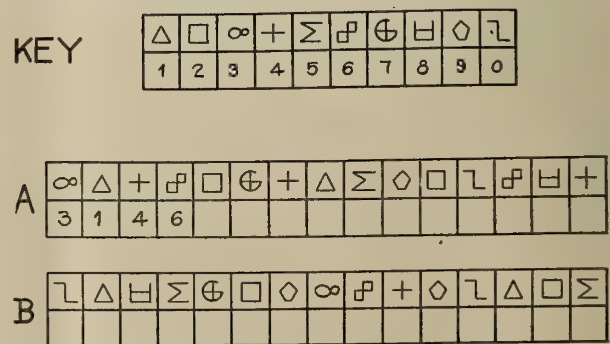
Look at each row of pictures. The first three in each row are alike in some way. Find the one other drawing in the same row that is most like the first three and put a cross under it.



N V A

TEST 4

Make under each drawing the number you find under that drawing in the key.



MENTAL TESTS FOR SCHOOL CHILDREN PREPARED BY A COMMITTEE OF THE NATIONAL RESEARCH COUNCIL

natural sequence of events. Test 3 demands comparison and the recognition of degree of similarity. Test 4 demands rapid habit formation and memory.

These tests were given to more than 5,000 children late in the spring of 1919. The results were then carefully studied and from among the tests which had been thoroughly tried ten were selected for further use. These were finally arranged in two groups, five tests each. The first group is to be called Examination A, or Intelligence Scale A. It consists of: (1) a test of arithmetical reasoning; (2) a sentence completion test; (3) a logical selection test; (4) a synonym-antonym test; (5) a symbol digit test. The second group, designated as Examination B, or Intelligence Scale B, consists of: (1) a test of computation; (2) an information test; (3) a vocabulary test; (4) an analogies test; (5) a comparison test.

Either of these two examinations may be given to an entire class in a period of thirty minutes. For the hasty survey of a school system in order to obtain a rough classification of the children by intelligence, either Examination A alone or Examination B alone may be used, but for more careful and accurate classification it is recommended by the committee that Examination A be given one day and Examination B at least one day later.

The examination papers can be scored rapidly by the use of printed keys or stencils which indicate exactly how the various items in each test should be answered. A child must be able to read English as well as the average third grade pupil in order to take these examinations satisfactorily, but the examinations demand very little writing, since, as in the case of the army examination, the responses to the tests are mostly indicated by making such simple marks as a cross, a circle, or a line in the appropriate place. For this reason the work is fairly easy and pleasant to the average child.

Each test in these examinations consists of from 15 to 40 different items, arranged in order of increasing difficulty. The first few items are usually so easy that a child of six to eight years can readily respond in the right way, but before the end of the test is reached the items have become so difficult that even a twelve-year-old child will frequently fail. A limited time is allowed for each test and this time is so fixed that only a few, and those the very quickest and brightest children, can possibly finish the test.

These intelligence examinations supply a reasonably accurate measurement of the intellectual ability of each child examined. The measurements may be expressed either in terms of the number of points scored in the examination, by letters as in the army, or by indicating where the child belongs in the group of American school children, as, for example, among the highest five per cent. It is unquestionably important that re-examination be made once or twice a year, in order to verify or correct the intelligence rating and classification, so that no injustice shall be done the individual. Heretofore the psychological examining of all children in the public schools has been practically impossible because each individual had to be examined separately and alone, the time varying anywhere from thirty minutes to an hour. Under these conditions only children who failed to make satisfactory progress or were difficult to manage could be given examination, for the examiner never had the time or assistance to classify all pupils. The group method of examining radically alters the situation, for it makes it possible to examine an entire class in the time that it formerly took to examine a single pupil.

The individual examination, it is true, ordinarily supplies a somewhat more reliable measure because in any group some individuals are likely to fail, for one reason or another, to do justice to their ability. This, however, is merely an argument for re-examination by the group method in order that the chances of serious injustice may be minimized.

The really important contribution of the group method of psychological examining to educational classification is the school survey. It will undoubtedly become the practice in progressive school systems to examine all pupils psychologically for the purpose of intelligence classification at least once each school year and possibly twice. This kind of survey can be carried out with very little extra expense to the school, because the methods in question can be used effectively by any intelligent teacher who has had a few hours of intensive training in this kind of work. The results are wholly objective, that is, independent of the judgment of the teacher as to how the items of the test should be answered, and likewise independent of the teacher's previous estimate of a child's ability. On the child's school record card the intelligence rating should be entered, just as the address, age, school grade, and so on, are recorded. It is merely an additional item of information concerning the pupil, but as it happens it is one of the most important items for educational and vocational purposes that can possibly be made available.

Although the school survey or wholesale classification of children by intelligence is likely to play a conspicuously important rôle in future educational development, it is quite clear that methods of individual examining should be continued and improved, for the group method of examining will constantly bring to the attention of teachers and of psychological specialists in school systems pupils who are mentally exceptional in one way or another. Some will be exceptionally dull or backward; some just the opposite; others will exhibit peculiarities of emotional life or of temperament which seriously interfere with school work. In any case a careful individual examination by a thoroughly competent person is urgently desirable and is indeed due the child.

A NEW METHOD OF DETERMINING THE SPEED OF SOUND IN THE WATER.

THE first attempts at determining the speed of sounds in water were made by Colladon and Sturm at Lake Leman in 1827, the results forming an accepted standard. Various physicists, however, have studied the problem in more detail since then in the interests of greater precision. For example, they have endeavored to ascertain the possible influence of the temperature of the water and of the presence of dissolved liquids or gases in water. A French scientist, M. Marti (the author of a system to take ocean soundings by the acoustic method, *i. e.* by measuring the time required for the noise of an explosion occurring at the surface of the water, to return to the latter after being reflected from the bottom), has recently renewed his researches with respect to the velocity of sound in sea water under given conditions of temperature and of salinity. M. Marti's experiments were made in the roads at Cherbourg at a depth of about 13 meters. Three deep water microphones were anchored in the same alignment parallel to the great dike at a distance of about 900 meters from each other. The sound waves were produced by the detonation of explosives placed upon the same alignment as that of the microphones at least at a distance of 1,200 meters. The passage of the front of the wave to the different microphones respectively was registered by means of a standardized tuning fork and a recorder. Under the conditions then existing the velocity of the sound wave was about 1503.5 meters per second at a temperature of 14.5° C. with a density of water of about 1.0245. M. Marti estimated that the possible error ought not to be more than 50 centimeters, *i. e.* 1/3,000 of the value. These figures differ perceptibly from those given by Colladon and Sturm who found the speed of propagation per second to be 1,435 meters in Lake Leman at 8° C. Marti found it to be 1,399 meters in distilled water at 4° C. while Doersing gives it as 1,441 meters in water containing no air at 13° C. and 1,470 meters in a 1/10 solution of chloride of sodium (common salt) at 15° C.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

DUPLEX CAR AND ENGINE.

DESCRIPTION of a light British car with an unusual type of engine.

The Duplex motor is of the single-sleeve duplicated-piston type with the pistons running in conjointly twined cylinders.

The motor, Fig. 1, consists of a detachable headed monoblock of 8 cylinders of only 56 mm. (2.20 in.) bore by 75 mm. (2.95 in.) stroke.

The ports, inlet and exhaust, are cut half around the outer side of each cylinder and are opened and closed by crankshafts through tiny connecting rods attaching to lugs at the bases of the sleeves (Fig. 2). These sleeves which are of cast iron carry three rings each, the top one wider than the

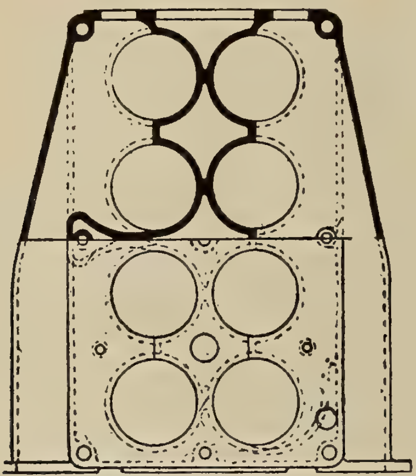


FIG. 1. DUPLEX SLEEVE VALVE MOTOR, PLAN VIEW WITH HEAD BLOCK DETACHED, SHOWING THE SEMI-CIRCUMFERENTIAL PORT AREAS

other two and as the ports are 5/16 in. deep on the exhaust side and 1/4 in. deep on the inlet, the construction gives a large valve area with a comparatively slight sleeve motion (1 1/8 in.).

The pistons carry their three rings on the middle of their trunks and the gudgeons rather lower than usual, because of the connection in each pair to a common crankpin on the short 4-throw crankshaft.

The crankshaft is mounted at the ends only in two roller bearings, the rollers being hollow to enable them to be link-caged and distanced somewhat like the rollers in a chain. The sleeve shafts, on the other hand, are mounted in long plain bearings with bolt thrusts at the end and drive is by helical gearing from the front end of the crankshaft. The sleeve shaft also carries an eccentric actuating a horizontal piston pump internally spring loaded which draws oil from a large deep rearward pump by way of a non-return ball valve (right-hand side of Fig. 2) and delivers it downward again to a gallery lead in the casting for distribution to four transverse troughs from which dippers on the big ends effect splash lubrication to all interior surfaces.

It is claimed that this design permits obtaining rather interesting physical results; namely, a cylinder capacity of approximately 80 mm. (3.15 in.) by 75 mm. (2.95 in.) halved in area so as to produce a simultaneous effort under the medium long stroke or internal combustion conditions of 56 mm. (2.20 in.) by 75 mm. (2.95 in.). It is claimed that in this manner all the capacity of the short-stroke type is obtained for sustained high speed without its extravagance and jerky inflexibility at low and medium speeds. In fact, it is claimed that the motor is obtained in which the power curve comes practically in a straight line from the rated 10 h.p. at 1,000 r.p.m. up to 33 h.p. at 3,000 r.p.m.

As regards the valve mechanism, it is stated that the valve shafts having only frictional resistance to overcome are doing next to no work and their rotation absorbs little power, while the system affords easy timing. It is claimed the motor presents unusually good cooling facilities.—*The Auto Motor Journal*, January 15, 1920, pp. 66-68.

PRODUCER GAS FOR MOTOR VEHICLES.

GENERAL discussion of the advantages and disadvantages of the use of producer gas for motor vehicles, followed by a description of some attempts to do it on a practical scale—among others, those made by the author of the paper himself.

In the opinion of the author the ordinary producer is larger and heavier than it might be and one of the reasons for

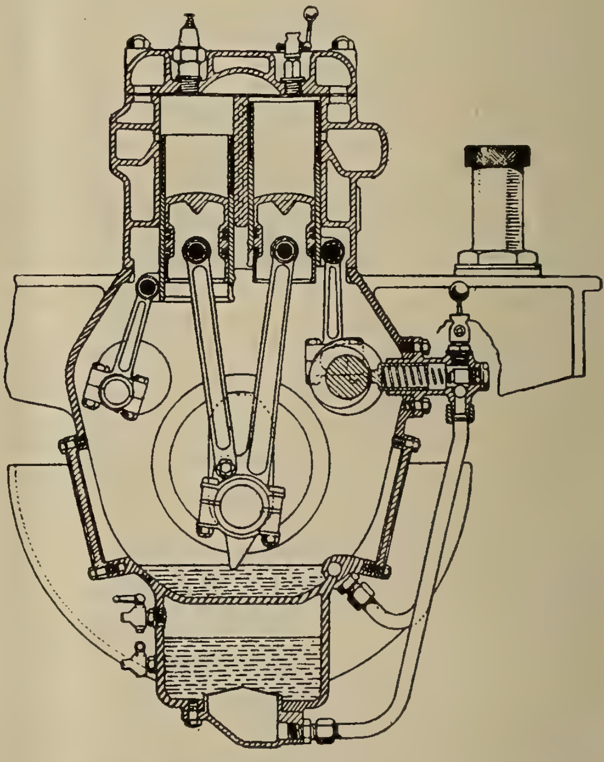


FIG. 2. DUPLEX SLEEVE VALVE MOTOR, SECTIONAL END VIEW FROM THE FRONT

this condition is that a very deep fuel bed is employed. To get away from this excessive weight the author resorted to the use of a thin belt of fuel which made it necessary to maintain two things: (1) a regular feed of fuel in small measured quantities, and (2) continuous agitation of the whole fuel bed in order that no channels or holes in the fire might occur, and that all ash might be constantly sifted out and the fuel bed kept light and porous to give easy passage to the air and water vapor through it. In the producer used by the author the depth of the furnace chamber was approximately 12

inches, the depth of fire being only 6 inches and it is stated that the producer with such a thin bed of fuel works very low, and that of anthracite, semi-anthracite and hard non-caking steam coal only dust is found in the scrubber.

The feed and grate mechanism were driven by the engine of the vehicle and a mechanical ash discharge was also added. This enabled a further reduction in the size of the producer by doing away with the necessity of providing an ash pan large enough to contain the ash formed during some hours' running.

As great flexibility in the operation of the producer was desired, it was found that water could not be fed directly to the fire which made it necessary to feed it as steam, and further in order to keep the quality of the gas constant the air passing to the producer had to be used as a regulating medium for the steam supply. A small vaporizer or boiler was therefore fitted to the producer heated by radiation through the fire and the passage of gas through a channel formed in it. (Figs. 3 and 4.)

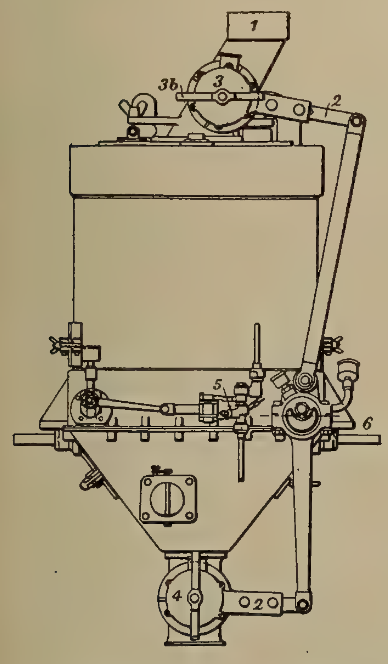
The effect of varying level in the vaporizer due to the rolling of the vehicle on uneven road was overcome by a device described in the original paper.

The producer as shown in Figs. 3 and 4 was controlled only by the speed of the engine. A throttle to the air inlet to the vaporizer was fitted, through which all air admitted to the producer had to pass. This throttle was coupled to the engine throttle, so that as the engine throttle was opened the throttle on the air inlet was partially closed. The result of this was to lower the boiling point of the water in the vaporizer, which then gave off steam freely owing to the drop in atmospheric pressure or slight vacuum to which it is subjected.

In addition to that it was, however, necessary to regulate the action of the producer also by the load on the engine which was done by means of an arrangement in which the stroke of the fuel-feed device and the stroke of the water pump were varied.

As regards the question of scrubbing the device shown in Fig. 5 is claimed to have solved the problem of making it automatic. This device is in three sections (1) the feed heater; (2) the cooling tubes: (3) the filter tubes.

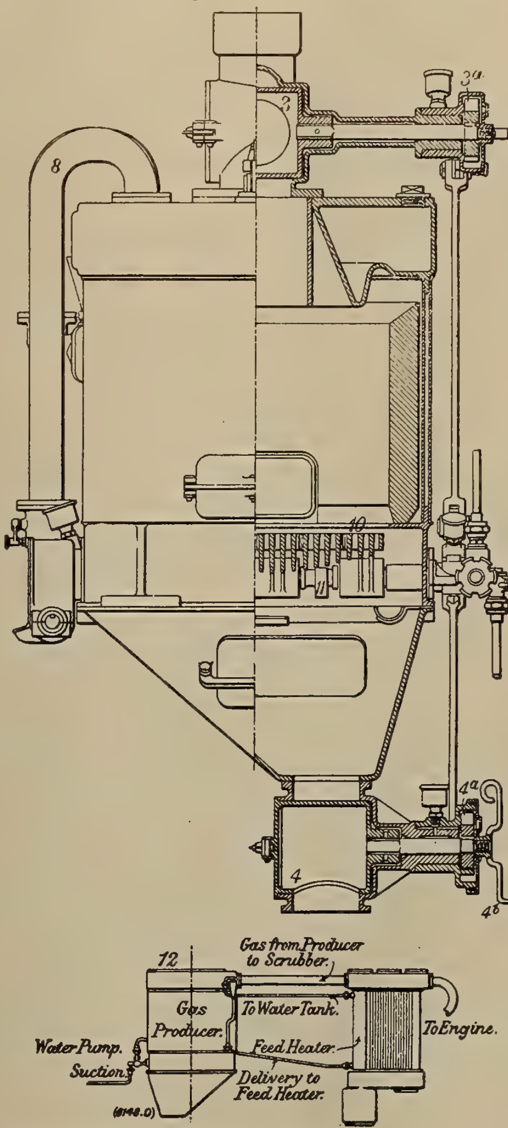
The gas from the producer enters the top header at the left hand end, and passes down the internal tube of the feed heater, which at the lower end is coned, and this tends to increase the velocity of the gas. The gas then expands into a settling chamber or pot, and in doing so drops a very large percentage of dust in suspension. It then leaves the settling chamber by an annular passage and passes up and down two or more banks of cooling tubes. In these tubes and the headers more dust is deposited. Finally, the gas passes up two or more large diameter tubes, which are fitted with fine gauze filters of conical shape, and filter fitting the bore of the tube at the lower end; to this a cross handle is attached, which allows the filter to be easily withdrawn through the door in the top header. An arrangement is also provided whereby any filter can be closed off and withdrawn for cleaning without stopping the action of the producer, but this is not likely to be required for vehicle work. The gas on leaving the filters is clean enough for all practical purposes and carries



1. Fuel inlet pipe
2. Adjustable fuel feed and ash-discharge gear.
3. Fuel feed valve.
3a. Friction drive for feed valve.
3b. Handle for independent hand operation of feed valve.

(Note that the position of the handle indicates the location of the feed aperture.)

4. Ash discharge valve.
4a. Friction drive for ash discharge valve.
4b. Handle for ash discharge valve (Similar to that on fuel feed valve.)
5. Water pump.
6. Main operating gear shaft driven direct from engine.
7. Totally enclosed and continuously lubricated driving gear for fire-bar camshafts: these also drive the water pump, fuel feed valve and ash discharge valve.
8. Pipe conveying steam and air to the underside of the fire.
9. Air supply pipe from interior of jacket to vaporiser.
10. Fire bars, alternate sections pivoted at alternate ends, the free ends being vibrated section by section and successively by cams on revolving shafts.
11. One of the cams for vibrating the fire-bars.
12. Diagrammatic arrangement of producer and scrubber.



FIGS. 3 AND 4. GENERAL ARRANGEMENT OF THE SMITH PORTABLE GAS PRODUCER PLANT

no more dust than is drawn into the air inlet of a carburetor when the roads are dusty. The cleaning of the filter is simple, and only takes two or three minutes. The doors are opened, the gauze filters withdrawn and water is poured in at the top doors and all dust washed out; the gauze filters are then shaken and replaced. The water from the feed pump on the producer enters the feed heater at the bottom opening and leaves at the top of the vaporizer. This cools the gas considerably and also recovers much valuable heat which would otherwise be lost. The combined feed heater and filter is very small and can be easily accommodated on the dashboard on the side opposite to the producer. Many other forms of filters will no doubt be possible, but the author thinks it will be difficult to evolve a design which at once meets the requirements and is of less weight and size.

The material found in the filter is merely the fuel dust,

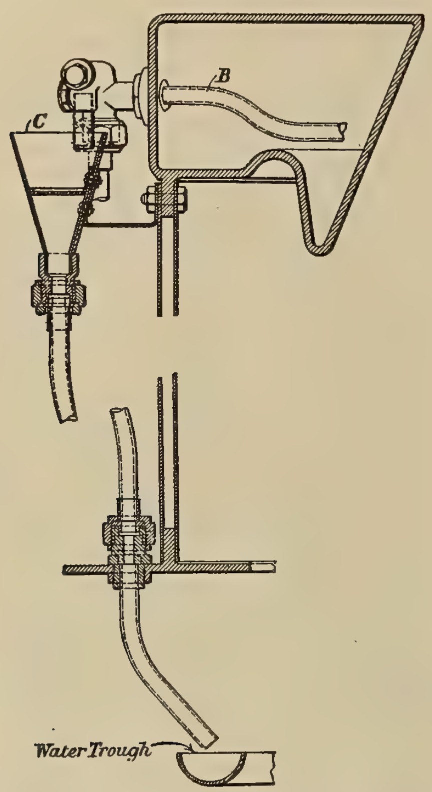


FIG. 5. SCRUBBER FOR THE SMITH GAS PRODUCER PLANT

which is quite dry and clean, and no trace of any tarry substance likely to cause trouble with the engine has ever been found.

The mixing valves and refractory lining of the producer are described in some detail. As regards the weight of the producer, it is stated that the plant which has a grate 12 inches in diameter, equivalent to 50 h.p., weighs with its connections approximately 2.75 cwt. (308 lb.), corresponding to a weight of 6 pounds per horse-power, notwithstanding the fact that cast iron was used throughout. This does not include, of course, the weight of the engine itself, but only that of the prducer and its appurtenances.

As regards the engine design, the author states that the conventional gasoline engine is entirely unsuitable for use with producer gas. With such a cheap fuel a large comparatively slow running engine could be used with approximately the same characteristics as a stationary engine. A higher compression with a half-compression device is essential, as a pressure of 120 to 150-pound gage would be necessary to obtain a fair economy with producer gas. The author recommends, for example, an engine such as the four-cylinder stationary type, 6½ inches in diameter by 7½-inch stroke, running at 600 r.p.m.

As regards fuels, the author tested anthracite, semi-anthracite, coke, charcoal, peat, maize cobs and straw, all of these fuels proving satisfactory under certain condtions.

In an editorial article on page 85 of *Engineering* for January 16, 1920, attention is called to the fact that in the paper no information is given as to the degree of reliability to be expected from the system described by J. D. Smith, a point which would be of interest to prospective users especially if they had had experience with stationary producer plants.—Paper by *D. J. Smith*, read before the Institution of Automobile Engineers, January 8, 1920, abstracted through *The Automobile Engineer*, January, 1920, pp. 22-32, and *Engineering*, January 9 and 16, 1920, pp. 59-64 and 92-95.

A PECULIAR TYPE OF INTERCRYSTALLINE BRITTLENESS OF COPPER.

WHEN copper is heated in a molten bath of sodium chloride for the purpose of cleaning and softening, it has been noticed that the copper was embrittled. Under these conditions the copper is more or less in contact with iron or steel, either from a stirring rod, forceps for handling the piece or the pot used to contain the salt, and a "galvanic couple" with the copper as cathode would be formed.

Experiments were made with small rods of copper and mild steel which were made either anode or cathode in a bath of molten salt and with an e.m.f of approximately six volts. The brittleness of the copper rods was compared with untreated material by bending the specimens back and forth with one end firmly clamped.

The copper rod which was an anode was as tough and soft as the original and required practically the same number of bends to cause it to fracture. The cathode copper was found to be very brittle.

Microscopic examination showed the anode copper to be perceptibly smoother on the surface than the original material; the structure was that of annealed copper. In the cathode copper rod the crystalline boundaries on the surface are well defined and the intercrystalline boundaries for an appreciable depth within the metal are made wider.

The probable explanation of embrittlement of the copper when it is made the cathode is that an appreciable amount of metallic sodium is formed by the electrolysis which immediately alloys with the copper, the attack being selective towards the grain boundaries rather than forming an alloy layer of uniform thickness upon the outside.—Abstract of *Technologic Paper of the Bureau of Standards*, No. 158. *Henry S. Rawdon* and *S. D. Langdon*, authors.

MECHANICAL STOKERS ABOARD SHIP.

PROGRESS of the application of mechanical stoking aboard ship. It is claimed that the introduction of oil fuel holds back their wider adoption at present. The adoption of mechanical stoker-feed aboard ship is clearly related to the introduction thereon of the water-tube boiler, and this latter is opposed in some quarters because of its alleged inferiority to the Scotch boiler in respect to reliability.

The author points out, however, that the experience of American war vessels and the vessels of the Emergency Fleet Corporation has shown that when properly handled the water-tube boiler is highly reliable and instances are given to prove this contention.

Fig. 7 shows an installation of Riley multiple retort under feed stokers such as carried out by the Erith Engineering Company of London. In this case it has been adapted to the Babcock & Wilcox-type cross-drum water-tube boiler built with tubes 14 feet long. The boilers are installed athwart ship.

Owing to the moderate continuous load very high combustion chambers are not required, the long pattern stoker operating at comparatively low combustion rates. The stoker, of course, cleans itself of ash; the coal is mechanically handled making on shipboard an installation closely similar to a modern stationary steam plant. Furthermore, the equipment does not occupy as much space as the usually installed Scotch

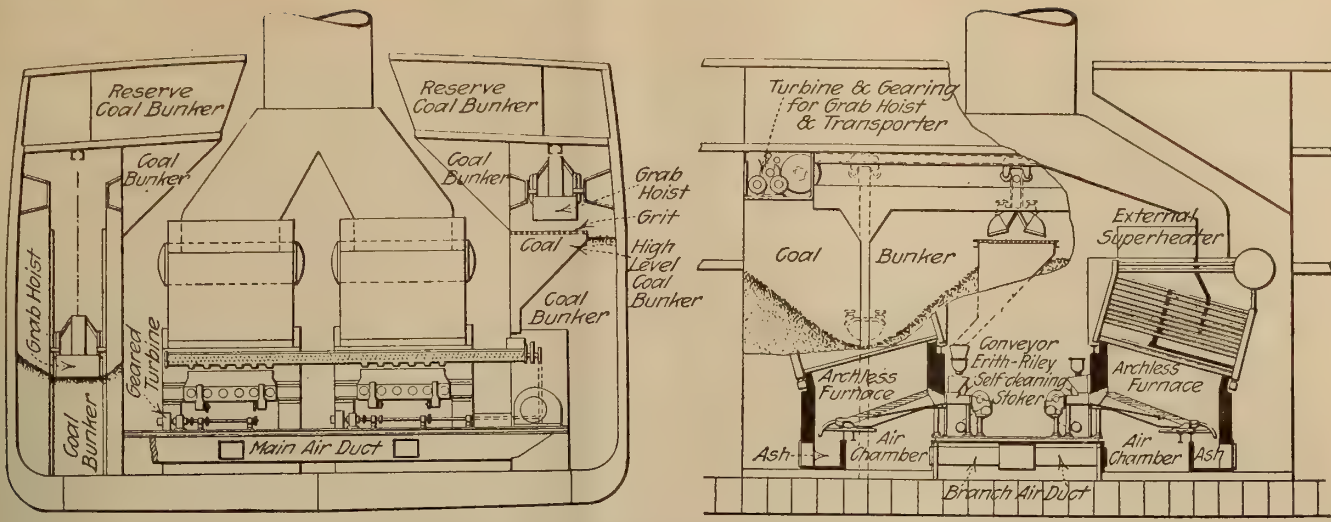


FIG. 7. RILEY MULTIPLE RETORT STOKERS AND MECHANICAL COAL HANDLING AS INSTALLED BY ERITH, OF LONDON. INSTALLED ON NEW SHIPS ONLY

boiler of equivalent steaming capacity and the weight is much less also.

The Emergency Fleet Corporation follows a somewhat different line of design, as one can see from Fig. 8. The characteristic feature of this type of installation is the baffling found by experiment with the assistance of the Bureau of Mines and claimed to enable getting the most heat out of the flue gases and into the boilers.

Here also plenty of room is provided for ash deposit and removal at the refuse end of the stokers (the coal-handling machinery is not shown).

These boilers are very much lighter for a given steaming capacity than the Scotch. The Heine boiler of 3100 sq. ft. heating surface, 225-lb. pressure, hand-fired, without grates but inclusive of water, weighs 60 tons. The Scotch of 3032 sq. ft., 220-lb. pressure, weighs dry 68.48 tons and requires 29.62 tons of water, making a total of 98 tons, as against 60 tons for the water-tube. The 8,000- to 10,000-ton ships of 11 knots speed need three such boilers. The saving in weight alone per ship is, therefore, appreciable.

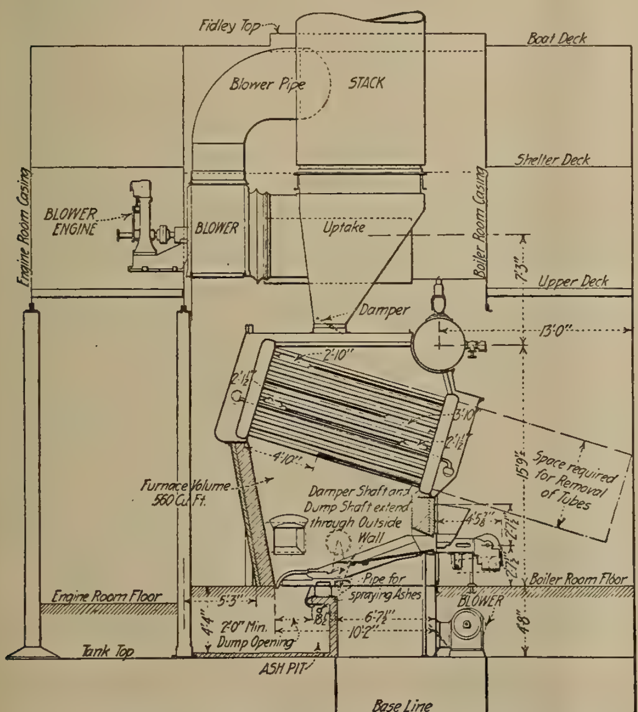


FIG. 8. GENERAL LAYOUT FOR WATER TUBE BOILER AND RILEY MULTIPLE-RETORT FOR SHIPS OF EMERGENCY FLEET CORPORATION

While the mechanics of the application of mechanical stokers aboard ship has been fully developed by the engineers of the Emergency Fleet Corporation the stokers will not be applied to the ships owing to the low price of fuel oil to the corporation. It is now somewhere in the neighborhood of $2\frac{1}{8}$ cents a gallon, which beats coal out of running. During the war, however, the Government had to pay from 7 to 9 cents per gallon for oil and it is now believed that the present low price will not stay very long.

The navies of the world will use oil regardless of price. So, too, will fast passenger ships. It is believed by many that there is not enough oil to warrant its wide use in the merchant marine for many years, although within recent weeks rich oil finds are reported from Colombia. Just now American coal is selling in Italy for $36 a ton. The freight rate is $22. So it is not bad business now to use oil-burning ships in the coal trade to Europe. Yes, the mechanical stoker for ships is here, and when oil again becomes high-priced or its supply alarmingly diminished, it will come into its own.—*Charles H. Bromley* in *Power*, Jan. 20, 1920, pp. 86-89.

FATIGUE AND ITS EFFECT ON PRODUCTION.

A PAPER by A. Vautrin in *Technik und Wirtshaft*, published by the Verein-deutscher Ingenieure, vol. 12, No. 11, Nov., 1919, p. 748 and following, discusses in an interesting manner the nature of fatigue and its influence on productivity of labor, accidents, hours, etc.

It has been known for some time and experimentally established by Kraepelin that all work whether physical or mental done by man is accompanied by a series of reactions which either favor its continuation or oppose it.

The most important of its reactions opposing the tendency to continue working is known as fatigue and may be of physical or mental character or a combination of the two.

As regards its physical nature, it appears that all work produces in the body materials (chemical or organic) which exert gradually a narcotic effect on the central organs of the nervous system. In fact, Weichardt claims to have established in animals the presence of a poison produced by fatigue which he calls kenotoxin.

Fatigue may be either physical or mental. In physical work certain groups of muscles are in action, thereby producing a corresponding excitation in the central nervous system. Muscular fatigue takes place therefore partly on the muscular periphery and partly at the brain center and the more demand is made on the brain center the greater the final fatigue. Purely mental work creates a demand on the large brain, which means a gradual exhaustion of the gray mat-

ter and a certain demand on the nervous ganglae connected therewith. In either case, however, sooner or later there follows an exhaustion of the organs brought into action.

Moreover there is a close connection between physical and mental fatigue and it is a well-known fact that when the body is overtired for any considerable length of time, this also reduces the ability of the brain to do mental work. The reason for this is clear. All work may be physiologically considered as a process of consumption which calls into play not only the organs directly producing the work but more or less

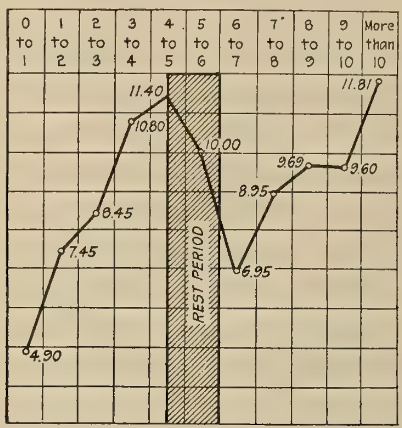


FIG. 9. DISTRIBUTION OF ACCIDENTS IN THE CHEMICAL INDUSTRY DURING THE WORKING DAYS IN THE YEARS 1897-1907

all the energy reserves of the body. Hence, bodily exhaustion will gradually lead also to mental exhaustion, and an overburdening of one part of the body by products of fatigue will nesessarily sooner or later affect the operating ability of all the other parts of the body.

Fatigue is only a moderate degree of the lowering of the producing ability of the body due to exhaustive work. A greater degree thereof is known as exhaustion and the difference between the two is stated as follows: Fatigue leads to the lowering of the ability to perform work; exhaustion repre-

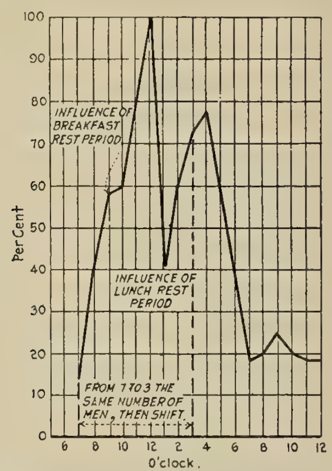


FIG. 10. DISTRIBUTION OF ACCIDENTS IN A GERMAN CABLE FACTORY THROUGHOUT THE WORKING DAY

sents a state at which the performance of work becomes entirely impossible. Physiologically, exhaustion represents such an accumulation of the products of fatigue that the body is unable to reconstuct itself for the time being.

A clear difference must be made between fatigue, which is an objective phenomenon and represents the actual failing in the ability to perform work, and the subjective feeling of fatigue, namely, tiredness. Whereas fatigue is produced by the actual physiological processes of exchange of materials in the body, tiredness may be the result of various conditions and circumstances lying often entirely outside of the effort to produce work. Fatigue is a physiological phenomenon; tiredness psychological. It may be due to lack of interest in the work performed, outside happenings in the life of the workman, etc. These facts have been established by an investigation made by Marie Bernays on the tiredness of workmen in the Gladbach Textile Works. It was found there that it is the highest paid workmen, those which work most carefully that get tired most quickly, because the work becomes a torture to them.

The degree of tiredness depends mainly on the condition of the workman and the same amount of effort will produce a greater tiredness in a weak man than in a strong man, in a man poorly nourished than in one well nourished, in boys and women greater than in grown-up men.

The paper brings some facts in confirmation of the claim often brought out before that there is a distinct connection between fatigue and accidents. Although the author makes it clear that he does not consider accidents as being due to fatigue. From his data it would appear that in hours when the fatigue of the workman is still light there are scarcely any accidents, while in the sections of the working day or week when the fatigue has grown to an appreciable extent the number of accidents is more than double the average. Figs. 9 to 11

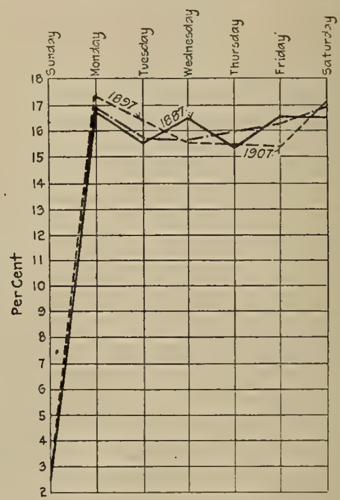


FIG. 11. FREQUENCY OF ACCIDENTS IN THE VARIOUS DAYS OF THE WEEK COMPUTED PER 100 WOUNDED OR KILLED PERSONS

together with tabular data in the article, would indicate that interruption of the working day by rest periods reduces accidents very materially and that of all the days of the week Saturday, the day when fatigue is at its climax, is also the worst day from the point of view of accident occurrence, particularly where the Saturday half holiday is not employed.

These statistics were collected in Lower Frankonia in 1895:

With a 9½-hour working day there were 1.1 accidents per 100 workmen.

With a 10½-hour working day there were 2.0 accidents per 100 workmen.

With a 13-hour working day there were 13.2 accidents per 100 workmen.

More than 13-hours there were 17.0 accidents per 100 workmen.

In printing establishments the accidents for the years 1910 to 1913 were on an average distributed in the following manner through the days of the week:

Sunday	136
Monday	535
Tuesday	583
Wednesday	530
Thursday	543
Friday	580
Saturday	585

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

MERCURY ARC RECTIFIERS FOR LARGE OUTPUTS.

Since the mercury arc rectifier entered the field of industrial application its theory, as well as its general construction, has been the subject of numerous publications. It is, therefore, hardly necessary to touch here on the principles involved. It will suffice on this occasion to recall that the "vacuum tube rectifiers" of Mr. Cooper Hewitt have been known since 1902. The current capacity of such rectifiers is limited by the maximum permissible size of the platinum leading-in wires, but nevertheless they have been successfully constructed for currents up to 100 amperes, after which an increase of capacity is only obtainable with a reduction in the life of the apparatus. Such rectifiers have been extensively used with excellent results for battery charging for the supply of small motors and arc lamps in series.

The loses in the mercury arc rectifier are equal to the product of the current and the pressure drop across the arc. The latter is independent of the current value—it varies from 13 to 20 volts according to the pressure at the terminals. Consequently the efficiency of rectifiers at high pressure is very high—for instance at 500 volts an efficiency of 95 per cent can be obtained which remains practically constant down to very light loads.

The favorable results obtainable with apparatus of low output encouraged the Société Anonyme Brown, Boveri & Company to investigate the question of building rectifiers for large outputs. A "Rectifier Company" was formed by the firm in 1912 in Glaris, Switzerland, for the purpose of carrying out the necessary experimental work. The technical staff met and overcame numerous difficulties of a practical nature. Large metallic chambers sufficiently gastight to enable the maintenance of a vacuum of 0.02 mm. of mercury were constructed. Then the insulated terminals for the conductors carrying the current to the electrode, required the invention of joints which should be perfectly gastight. Again, it was necessary to provide means for preventing short circuits between the anodes which may occur when an arc is started between two fixed electrodes. It is possible to prevent them by carefully choosing the position of the electrodes in the apparatus and by compelling the arc to follow a predetermined path with the aid of shields and suitable guides. Another danger that had to be guarded against consists in the discharges which may occur between the anodes and the neutral substances in the interior of the chamber; the latter may cause a black deposit in the rectifier and rapidly put it out of order.

Since 1915 the Brown, Boveri & Co. have been able to construct thoroughly reliable rectifiers of large output. Further improvements were made in their 1917 models. The larger units are water-cooled. The arc chamber is provided with a water jacket, while coolng water also circulates around the condensing cylinder, the cathode and the cover carrying the anodes. Further the anodes are cooled by means of ribbed cylinders (containing water) surrounding their upper extremities. In the case of rectifiers working at less than 600 volts d.c. pressure, and provided that both poles are insulated, running water from the mains may be used if it is of suitable quality. In all other cases a self-contained system is installed consisting of a radiator located in a convenient position, and a pump.

A vacuum is created in the arc chamber by means of a two-stage vacuum pump which is an essential accessory to each installation; with these pumps a vacuum of 0.005 mm. mercury is obtainable. After a rectifier has been a few months in service the mercury seals are properly formed and the cylinders are then hermetically sealed. Further operation of the vacuum pump is not required as a rule—any slight decrease of the vacuum which may be observed when the apparatus is not on load is compensated under working conditions by the absorption of the gases by the arc. The vacuum pump has been so designed that it requires no supervision during operation, and as no oil can escape from it should the pump stop accidentally, service interruptions caused by oil escaping from the pump and thus allowing air to penetrate into the rectifier are avoided. The actual degree of vacuum varies from 0.01 to 0.1 mm. of mercury, and it is sometimes found in practice that an electrical method of measuring the vacuum is preferable to the use of the McLeod vacuum gage.

As the internal construction of this class of rectifier remains practically unchanged for working pressures between 110 and 800 volts, a few standard sizes—graded in accordance with the current output—cover a wide range of requirements. Up to the present two sizes have been standardized, namely for 250 and for 500 amperes. Larger outputs have so far been dealt with by employing a suitable number of cylinders in parallel. It is said that pressure up to 2,400 volts can be dealt with. A third standard size—for 1,000 amperes and 750 volts continuous rating, is now in course of construction. The aggregate capacity of the rectifiers already supplied, or under construction in the Baden works of Brown, Boveri & Co. amounts at the present time to over 30,000 kw.—From *The Electrician* (London), Jan. 2, 1920.

THE HUMAN BODY AS A CONDUCTOR OF ELECTRICITY.

By Prof. M. Gildemeister.

The rapid strides of the electrical industry have greatly increased the human comforts in many directions, unfortunately this has been accompanied by the loss of human life due to electrical accidents. The protective devices would become more effective if based on a thorough knowledge of the conductivity of the human body.

There is a considerable amount of material on this subject to be found in the physical, physiological and medicoclinical works. However, there has never been an attempt made to review the whole mass of these single and very often contradictory observations and measurements from a common view point. This report seems to be the first such attempt based not only on the previous experience and observations but also on a mass of original experiments.

The more important contributions on this subject are: the book by Boruttau and Mann[1] and a recent paper in "Pflüger's Archiv für die gesamte Physiologie." Measurements on living bodies can be performed only with currents of low or medium density. Current densities that result fatally can be applied only to fresh corpses. Such tests have not been conducted as yet on large or systematic scale. Therefore, the results given here are perhaps not available for practical applications without further researches. On the other hand, it seems that with an increasing current density there is observed a certain uniformity of results which allows of judicious interpolation.

Further difficulties hindering the obtaining of right values of the resistance of the human body lay in the properties of the upper layer of the human skin in the variations resulting from size and distance of the electrodes, kind of current used

[1]Boruttau and Mann. Handbuch d. ges. Med. Anwendungen d. Elektrizität. Bd. 1 Berlin, 1909.

and its duration, voltage, frequency, etc. When the problem was even reduced to its simpler form of determining the resistance from hand to hand values were obtained varying in the ratio of 1:100. On this account an opinion was advanced that the resistance of the body is very variable and that it is greatly influenced by the blood vessels of the skin, the nerve system and similar factors. In reality these factors play an unimportant part.

The variations in the resistance of the human body will be better understood if we discard the assumption that it has ohmic resistance only. It is assumed that it has also inductance or capacity, or both. The results known so far are examined from this stand point, and this report is subdivided as follows:

1. Measurement with direct current.
2. Measurements with alternating current: A. Without consideration of the phase displacement (apparent resistance). B. With compensation for the phase displacement (actual resistance).
3. Simultaneous and comparative measurements with both direct and alternating currents.
4. Discussion of electrostatic or polarization capacity.
5. Theoretical considerations.
6. Data and constants.
7. Conclusions.

Measurements with direct current show that during the first few thousandths of a second (with constant current and

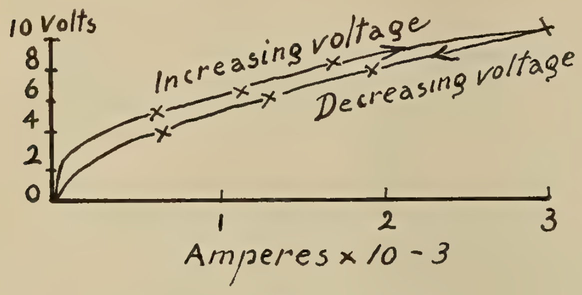


FIG. 1

voltage) the resistance is very low, the oscillograms taken showing a sharp current peak, on recovering its high initial value, the resistance then gradually decreases with time and after a certain period reaches a permanent value. With a pressure of 10 volts this more or less permanent value was reached after a period of 115 seconds. The resistance is also decreased with increase of voltage, a hysteresis effect being noticeable when the voltage is changed from higher to lower values and vice versa. This is clearly shown in Fig. 1.

With alternating currents there is observed a phase displacement with a leading current. The apparent resistance of the body decreases with time but not quite as much as the case is with direct current. Tests performed by Dr. Rasehorn of Siemen's and Halske show that with increase of voltage the apparent resistance decreases considerably, while the higher the frequency the lower is the apparent resistance.

However, when the phase displacement is compensated by a seld-induction according to the method of M. Wien[a] then the true resistance is, as shown by researches the results of which have not been made public as yet, quite constant with time, slightly increases with increase of voltage and greatly decreases with increase of frequency.

These phenomena could be explained by the theory of electrostatic capacity, the skin acting as a dielectric. However the experimental work seems to disprove this hypothesis and confirm a new theory, namely that of polarization of the skin. According to the physiologists our skin cells are covered with semi-transmitting membranes which let water through but not the electrolytes filling our body. When such a membrane is traversed by a current the electrolyte adjacent to it is concentrated forming a concentration cell the pressure of which is opposed to the impressed voltage. The mechanism of polarization is thus the same as that of reversible metal electrodes.

The delicate membranes are now disturbed when in contact with an electrolyte of unusual degree of concentration, and if this condition lasts over a certain length of time the membranes suffer a deterioration and allow the electrolyte to filter through. This results in the decrease of the concentration difference and of the E. M. F. of polarization. With the breaking of the current the membranes seem to be able to recover their original properties. This polarization theory explains not only the variations of the resistance of the body with the kind of current, voltage and frequency but also its variations with time element and the hysteresis effect.

In view of the above theory the E. M. F. of polarization plays but a little part when the impressed voltages are high, as is usually the case in electrical accidents. It follows that the true resistance is that obtained by high frequency measurements. In case the skin is dry, there is an electrostatic capacity in addition to the polarization capacity. Then the body may be said to consist of two polarization cells in series, of a resistance between them, and of a very small condenser parallel to the whole circuit. It was also observed that in certain cases the polarization capacity of the skin forms, together with a self-induction, a system capable of oscillations and gives rise to resonance phenomena. These researches have not been completed.—Investigation made by the Physics Department of the Physiological Institute of Berlin. *Elektrotechnische Zeitschrift*, September 18, 1919, pp. 463-66.

[a]Annalen der Physik, v. 58, p. 37 (1896).

DAYLIGHT SAVING.

Historic Note.—In accepting the invitation of the Lighting and Illumination Committee to present a paper on "Daylight Saving" the author stipulated that a considerable part of the paper would have to be devoted to matters remote from electrical engineering, the economic and sociological aspects of daylight saving surpassing in importance the effect upon the use of artificial light.

Benjamin Franklin is considered to be the father of daylight saving. In modern times William Willett was sponsor in England for a proposal to advance the clock in summer time in order to utilize daylight to better advantage. On May 1, 1916, Germany as a war measure adopted the plan by advancing clocks one hour for the summer period, England, France and several other countries took like action within the next few months.

On this continent the experiment of advancing the clock had been tried in several localities with varying success. It was adopted in Cleveland in the spring of 1914. In Detroit which lies just within the boundary of the central zone the clocks were advanced on May 15, 1915, bringing the city into conformity with normal eastern time both in summer and winter.

After considerable agitation by the National Daylight Saving Association, the U. S. Chamber of Commerce and other bodies a bill passed both houses of Congress and was approved March 1918, fixing standard time to govern the movement of common carriers engaged in interstate commerce and other activities under Federal jurisdiction, and providing for the advancement of such standard time by one hour during the period between the last Sunday in March and the last Sunday in October. The states of New York and Pennsylvania adopted parallel legislation to govern state activities. The Federal Act remained in force for two years, but that provision which called for advanced time during the summer months was repealed in August, 1919.

In European countries such as England, France and Germany, the daylight saving plan will probably be followed

during the coming summer as in the recent past. In Canada, after a trial during 1918, proposed renewal of the daylight saving bill was defeated in the Dominion Parliament in 1919. It is understood also that in Australia after a trial daylight saving has been abandoned.

Since the repeal of the Federal Daylight Saving Act in this country the subject has been agitated locally in several cities. For example, in Cincinnati advanced time has been adopted to be effective during the entire year, thus conforming to the action of Cleveland and Detroit. In New York, Hartford, Philadelphia, Pittsburgh and other cities provision has been made for advanced time in municipal activities during either five or seven summer months. In Chicago after consideration it has been decided to adhere to normal Federal time. After a year's experience in England a Parliamentary Committee conducted an investigation of the daylight saving and reported in favor of its continuance. In the United States there has been no organized investigation of its operation.

ADVANTAGES AND DISADVANTAGES.

Reduced Use of Electricity and Gas.—A considerable amount of statistical data were examined. It appears that daylight saving reduces the total output of certain central stations and of one gas company by about three per cent during the seven summer months. A reduction in output for lighting alone is found to average 8 per cent. Applying these fragmentary data to the country as a whole there is estimated an annual saving by the public of $19,250,000 in expenditure for artificial light and a reduction of about 495,000 tons per annum in consumption of coal.

Other advantages of daylight saving are: Outdoor recreations and gardening. Gardening by those however who produce a surplus for sale has been impeded by the Daylight Saving Act. Upon the whole the evidence appears to be that the disadvantages to professional gardeners of daylght saving have outweighed the advantages to amateur gardeners. It is probable that real improvement has accrued to certain classes of urban and suburban dwellers.

There seems to be practically a consensus that advancement of the clocks in summer brings bedtimes for small children well into daylight and interferes with their sleep. Thus children either sit up later or after retiring remain awake longer by the clock than formerly.

As to the city tenement dwellers it may be stated that from all observations the daylight saving brings them only disadvantages during the summer months.

Disadvantages are experienced principally by farmers and dairymen. The crux of the difficulty is that much of the work in the country must be regulated by the sun. United States Senator Capper of Kansas estimates that daylight saving occasions wastes aggregating $1,000,000,000 a year. While definite figures are not available it is probable that economic losses probably far outweigh the gains.

Custom in allocating hours for work, sleep and play has been evolved through experience. It is undesirable to alter it by arbitrary legislation. It is important to "think nationally." To secure the greatest advantage to the whole people should be the aim. The very obvious solution of the problem appears to lie in diversification of hours of industry. There are certain classes of people in the cities and suburbs who are in position to derive benefit from advanced summer time. Without molesting the customs of an entire nation let them undertake an educational propaganda in favor of early rising and early retiring in summer time, together with advancement of the beginning of business hours from say 9 to 8 A. M. It will probably follow that where the advantages of such altered practice seem sufficient, business hours in certain kinds of work will be advanced with consequent diversification of the traction peak, bringing greater comfort to those who must travel in the rush hour. This will avoid local misadjustment of clocks with the attendant confusion which will arise from difference between Federal and local time.—Paper presented by *Preston S. Millar* at the 8th Mid-winter Convention of the A. I. E. E., New York, February 18, 1920. (*Journal of the American Institute of Electrical Engineers*, February, 1920, p. 146-158.)

ELECTRICAL EXPORTS IN 1919.

ELECTRICAL exports for the calendar year 1919 amounted to $89,089,711, which surpasses in value the exports of any previous calendar year. Especially heavy foreign sales were made in batteries, generators, insulated wire and cable, metal-filament lamps and motors, while miscellaneous material increased almost ten million dollars.

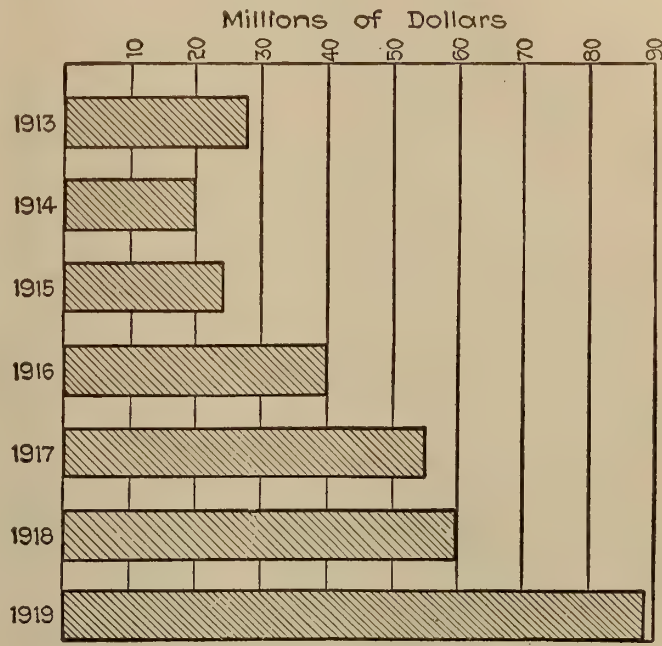


FIG. 2. SEVEN YEARS OF ELECTRICAL EXPORTS

This increase above 1918 of approximately 50 per cent in value of exports is not due entirely to increased volume of goods shipped; some of it is due to the higher prices which have been obtained during the year.

Because of unfavorable rates of exchange it is expected that exports during 1920 will not equal those of 1919. Of the four main foreign outlets—Canada, South America, Europe and Asia—the exchange rates of Asia (excepting Russian territory) and of South America are rather favorable, while those of Canada and Europe are unfavorable. Consequently it would not be surprising to find that Canada during 1920 had to recede from its present position as the single largest outlet for the United States manufacturers. At the same time the tendency is for domestic manufacturers to open branch factories in Canada, and this will lessen the amount of money that country will spend for foreign apparatus.

The accompanying chart shows the growth of our electrical exports for the last seven years.—From *Electrical World*, Feb. 7, 1920.

ELECTRIFICATION OF THE DRAMMEN RAILWAY.

THE contract for electrifying the section Christiana-Drammen has been awarded to a Norwegian amalgamation concern headed by A/S Per Kure. Work was commenced last summer, and the electric conductors are at site. The foundations for the masts will be constructed in concrete next spring, while the remainder of the material, including the masts, is being manufactured in a number of factories in Norway and Sweden. The section Christiania-Asker is to be finished by the end of 1920, and the remaining part of the section by the close of 1921.—*Teknisk Ukeblad*, Dec. 5, 1919. Abstracted by *The Technical Review*.

Progress in Mining and Metallurgy

A Summary of Important Articles

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

A NEW OCCURRENCE OF PRO-EUTECTOID FERRITE.

By Charles Y. Clayton.

Cast-steel runners, while not interesting from a commercial standpoint, furnish valuable material for microscopic study. Foley found not only the usual ingot structure, but zones of Widmannstättian structure, which he explains as due to differential crystallization. The writer, in examining nickel-steel runners, found a type of pro-eutectoid ferrite that is unusual and most probably new.

The runner in question was 8.75 cm. (3.5 in.) in diameter and analyzed at its center 2.69 per cent nickel and 0.350 per cent carbon and at its edge 2.62 per cent nickel and 0.359 per cent carbon. The macro-structure, which is the usual type, is shown in cross-section and the longitudinal surface, respectively. Slight segregation of ferrite can be seen near the center of the segment and at other points near the edges of polyhedral grains.

Stead's reagent brings out the dendritic structure within the grains. This texture is what would be expected of such a steel. Other figures show the peculiar swirls of pro-eutectoid ferrite, the finding of which prompted this paper. These swirls, or eddies, if such a term can be applied, occur in all parts of the runner and in all parts of the individual grains.

A possible explanation of these swirls of ferite is that the whirling motion of the molten steel in the runner causes the tips of the dendrites and dendrite branches to be rounded at different periods of crystallization due to resolution. Upon these rounded points, low-carbon autenite would be precipitated, due to selective freezing or the differential crystallization of Foley. Non-ferrous matter would, as a result, have a similar arrangement due to its stratigraphic history. Upon passage through transformation range, the arrangement of the pro-eutectoid element would be dependent on the previous distribution of the ferrous and non-ferrrous elements. Two cast nickel-steel runners from different heats exhibited this same peculiar occurrence of the pro-eutectoid element.—Abstract of paper to be presented at Lake Superior Meeting of American Institute of Mining and Metallurgical Engineers, August, 1920. From *Mining and Metallurgy*, March, 1920.

INDUSTRIAL REPRESENTATION IN THE STANDARD OIL COMPANY.

By Clarence J. Hicks.

The labor policy of the Standard Oil Co. (New Jersey) is founded on paying at least the prevailing scale of wages in the community; on the eight-hour day, with time and one-half for overtime; one day's rest in seven; sanitary and up-to-date working conditions; just treatment assured each employee; payment of accident benefits beyond the amount prescribed by the State compensation law; health supervision by a competent medical staff; payment of sickness benefits after one year's service; coöperation with employee in promoting thrift and better social and housing conditions; and assurance for a generous annuity at the age of 65, guaranteed for life after 20 years of service. Most of these features have been a part of the company's policy for many years, but it is only during the past two years that the coöperation of employees in determining these matters has been definitely assured through industrial representation.

Industrial representation, in the Standard Oil Co., is a principle rather than a procedure. Representatives of employees and representatives of management evolved a simple plan, the basis of which is that it gives every individual employee representation at joint conferences on problems and fundamental principles affecting all those interested in the industry. Experience has definitely shown that representatives of the employees are not only alert for the employees' interests but are as keen as the representatives of the management in determining and insisting upon fairness to the employer.

The plan was brought into operation by an invitation to employees to coöperate in maintaining the company's policy.

The joint works (or plant) conferences are held at regular intervals to consider all questions relating to wages, hours of employment, working conditions, and any other matters of mutual interest that have not been satisfactorily settled in the joint division conferences. These joint division conferences meet whenever needed to discuss and adjust matters within the smaller confines of a division. Many problems never go beyond the joint division conference, unless the problem develops into one that concerns other divisions. In case any matters are to come up on which the joint works conference could not agree, they would be referred to the Board of Directors for final decision. But as yet not a single case has been referred in this manner.—Abstract of a paper to be presented at Lake Superior Meeting of American Institute of Mining and Metallurgical Engineers, August, 1920. From *Mining and Metallurgy*, March, 1920.

OIL POSSIBILITIES IN NORTHERN ALABAMA.

By Douglas R. Semmes.

The possible oil territory of Alabama can be readily divided into two regions, the Paleooic area of the north, and the Coastal Plain province of Cretaceous and younger formations lying to the south. This latter area has received much attention in the last few years and has been described by a number of writers. Although the possibilities of the Cretaceous series have been much emphasized by recent writers, the fact remains that the two or, possibly, three localities where oil or gas have been found in anything like paying quantities are confined to the area of Carboniferous rocks. Moreover, almost all of the oil seeps and a good percentage of the gas seeps are confined to this area.

Topographically, as well as structurally, the Paleozoic area can be divided into three rather well defined provinces: (1) the broad, open Coosa Valley lying adjacent to the crystalline oldland, with comparatively little relief, except for occasional longitudinal ridges and rather intense folding; (2) the plateau region of horizontal or gently warped Pennsylvania strata broken by occasional anticlinal valleys alined northeast and southwest, outliers of the Coosa Valley proper, in which the older paleozoic formations are exposed—a region of much relief (200 to 300 ft.) and thorough dissection, well wooded, and of little agricultural importance; and (3) the Tennessee Valley region of horizontal or gently warped Pennsylvanian and Mississippian strata, where the relief is not so marked, the wooded area is less extensive, and the country is of more importance agriculturally.

OIL AND GAS HORIZONS.

The possible oil and gas horizons thoughout the section are rather numerous; many of these horizons have, locally, given very promising shows. Owing to the striking lateral variations in lithologic character, horizons that may at one point be promising have little or no possibilities at another; this is especially true in the Carboniferous series.

FUTURE PROSPECTING.

The area the writer considers most favorable for future testing is the northwestern portion of the state, where the Trenton limestone would be the producing horizon. Even this area is not without its disadvantages. The degree of metamorphism increases not only near areas of deformation but in depth in any locality. Therefore the degree of metamorphism of the Ordovician formations, once covered to great depth by the Pennsylvanian series, may be much greater than is indicated by the Pennsylvanian coals, in which case commercial accumulations would be improbable. Moreover, there is a possibility of an unconformity below the Silurian. Nevertheless, considering the structure, the lithologic character of the section, and the evidence of the carbon ratios of the overlying Pennsylvanian coals, the area is undoubtedly worthy of further tests, provided they be well located on carefully determined structure. In addition to this area, the Coal Measures, where exposed in Winston, Marion, and Fayette Counties, should be well worth testing, especially where drilling is continued to sufficient depths to test the Hartselle and the Trenton horizons.—Abstract of paper to be presented at Lake Superior Meeting of American Institute of Mining and Metallurgical Engineers, August, 1920. From *Mining and Metallurgy*, March, 1920.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

PAPER FROM BAGASSE.

While much has appeared heretofore upon the possibility of producing various grades of paper from bagasse, as the sugar cane from which the juice has been expressed is termed, these considerations have been based on experimental results and discussion of the possibilities based on these trials. *The Tech Engineering News* in its first issue, February, 1920, contains a description of the first commercial sized mill which has been put into operation in making a special paper from bagasse. The present method of operation is of course based upon experimental runs made in this country before the mill was built in Hawaii.

The article points out that failure in the past has been caused in part by the low yields of pulp obtainable from bagasse, and partly because the pulp has heretofore been converted into a quality of paper to which it was not well adapted. The further point is made that the manufacture of paper involves two distinct operations—the first being the production of pulp principally by chemical methods, and the second the mechanical operation of converting this pulp into paper. The pulp processes are, roughly speaking, either acid or alkaline in their nature, and the article in question gives a brief description of these typical processes. Either the soda or the sulphate process may be applied to the cooking of bagasse, which must first be separated by shredding and screening methods into pulp-making fiber and non-fibrous pith which is detrimental in paper making. The fiber is suited for the preparation of book or writing papers and the pulp is expected to find its greatest application in mixtures with rag, sulphate or soda fibers. The most suitable composition of the liquor in which the bagasse is to be cooked by the sulphate process is stated to consist of 15 per cent caustic soda and 7½ per cent sodium sulphite. About three parts of cooking liquor to one of the bone-dry fiber gives the most satisfactory yield. The time of cooking is five hours at 100 pounds pressure, or eight hours at 75 pounds pressure. If, however, the soda process is employed, a liquor with twenty-five per cent caustic soda is used for a period of five hours at a pressure of 100 pounds.

The primary product of the mill in question is a peculiar sort of paper made to meet the specifications of the Eckart process, which requires that the paper shall, when asphalted, withstand five or six weeks of weather, and at the same time be sufficiently soft and weak to allow the sharp growing points of the sugar cane to penetrate it. The apparent success of the Eckart process in the cultivation of cane has been the subject of much discussion, since experiments on large areas have indicated that the cost of growing the cane may be reduced from 50 to 70 per cent and the crop increased by ten tons per acre, equivalent to one ton of raw sugar. This simple method of weed elimination is of great economic importance, since the statement is made that in one district alone one million dollars has been spent annually for cultivation.

The paper, staked upon the fields over the cane rows, also serves to create a condition which causes more rapid and vigorous growth of the cane, as well as the sprouting of all weed seeds at a time when they are quickly blanched and withered beneath the black paper.

This grade of bagasse paper is prepared by cooking the bagasse for twelve hours with lime under sixty pounds pressure, after which the pulp is allowed to remain in storage for a few days, is then run out on the paper machine and afterwards treated with asphalt. The article in question is illustrated, including one view of a cane field four weeks after the paper has been spread over the cane rows. In this case the paper is held in place by cane field litter.

A NEW PLAN FOR RESEARCH CO-OPERATION.

In the January 10 issue of *Chemical Age* there is given an outline of a new plan for coöperation in research between one of our large technological schools—the Massachusetts Institute of Technology—and the industries. The plan is based upon the principle of reciprocity in which the point is made that the nation's strength lies in its industries and the industries in turn depend upon the technical schools for the most important element in their organization, namely trained men. The Institute in effect takes the stand that if the constant demand for suitably trained men is to be met and the Institute is to furnish its quota, it must have additional funds, and it is therefore proper for the industries who are to gain the most from the efforts of these men to supply the necessary resources. These funds have been secured by means of 153 contracts, totalling $1,810,875, and this sum is considered as retainer fees in return for which the Institute agrees to permit the corporations retaining her to consult the members of the staff and faculty on problems pertaining immediately to the business of the company; to use to the greatest possible extent the library, the files, and the facilities of the Institute, and to place records of the qualifications, experience and special training of the alumni at the disposal of these industries in an effort to assist them to strengthen their own organization. The Institute also undertakes to supply information as to sources of special knowledge in any given subject and to give these industries the first opportunities to secure the services of Technology graduates.

So far as is known, the plan thus briefly outlined is unique. Members of the faculty of educational institutions have frequently been retained as consultants by commercial interests, and manufacturers have always been encouraged to maintain

scholarships in science, preferably without restrictions, but sometimes upon special phases of science in which the donor has been interested. Another plan, having for its purpose the training of men while problems were in the course of solution, has been very successful as developed at the Mellon Institute. In the latter instance, the work has been conducted for the benefit of the donor of the fellowship, who has had exclusive use of the results for a limited time, and the men especially employed for any given problem have frequently gone into the industry. The Massachusetts Institute of Technology before the war put into practice another unique plan for the training of men which, under the name of the School of Chemical Engineering Practice, devised a plan whereby properly qualified students could be sent in groups for limited periods to stations chosen with reference to demonstrating the typical unit processes employed in chemical manufacturing operations.

To have an educational institution become a general consultant is an experiment which will be watched with great interest and the plan may conceivably go far beyond its original scope. The article mentioned ventures the opinion that ultimately the Institute may become the greatest consulting body in the country, and it would follow that since the great corporations of the country have retained the school as a consultant, the great experts of the country would ultimately be members of its instructing staff. It is also suggested that industry will ultimately go to Technology instead of having the instructing staff and students go to the industry, as is frequently done at present. It is not quite clear by what means the Institute will be able to attract and hold the country's greatest consultants, and the range of possible problems presented by 153 manufacturing establishments will undoubtedly require a diversity of talent for their solution which has heretofore seldom, if ever, been found in a single establishment.

The Division of Industrial Coöperation and Research is the designation of the new department of the Institute responsible for the successful execution of the new contracts.

A NEW FACTOR IN TEXTILES.

THE Textile Industrial Institute has been established for a number of years at Spartanburg, South Carolina, where a favorable arrangement with a nearby cotton mill has made it possible for students to work their way through school and become better fitted to occupy positions of responsibility in the cotton industry. Students have worked in pairs, spending alternate weeks in the mill and in the class room, putting into practice one week what had been learned the preceding. This plan kept a constant number in the mill and in the school.

The usefulness of the Institute is now being greatly extended through the erection of a model cotton mill, which its designers have tried to make the last word in design, construction, and equipment. The plant which has cost something more than $200,000, has been provided by the coöperative contributions of more than eighty cotton mills in the Carolinas and Georgia and an equal number of equipment manufacturers.

In this mill, which will be operated by the more advanced students of the Institute, raw cotton can be taken in and carried through every step to goods mercerized, singed, dyed but not printed, and finished for market. For example, there are eighteen kinds of looms in this model mill and cotton can be treated by any of the methods known in spinning, twisting, weaving, etc.

The importance of the plant becomes more evident when it is realized that heretofore the planter who has grown some new strain of cotton or for any reason is interested in knowing just what valuable characteristics a small portion of his crop has, has been unable to have complete trials made under manufacturing conditions. It has been difficult therefore to interest progressive planters in growing comparatively small trial crops, and manufacturers have doubtless suffered through the lack of information not to be gained otherwise. At the present time the mill is running on an entirely new kind of cotton from which great things are expected.

The school will be able to finance the operation of the mill by the sale of their products for which they have an accredited list of more than 11,000 customers very widely distributed geographically.

A CENSUS OF BLOOD CORPUSCLES.

IT has now been some time since methods were devised for calculating the approximate number of both red and white corpuscles in the blood, and the present-day diagnosis of many diseases is based upon this census of corpuscles. Refinements which mean greater accuracy depend upon staining the white blood corpuscles by methods which differentiate them in a way which enables the diagnostician to reach his conclusion with greater certainty.

The counting of blood corpuscles depends upon a glass cell one-tenth of a millimeter in depth, having one of its sides ruled into squares and rectangles. A very small quantity, say one cubic millimeter, of blood is drawn into a pipette provided with a mixing chamber in which a dilution of one to ten is made if white blood corpuscles are to be counted and one to a hundred if red ones are to be enumerated. Various diluting fluids and stains are used, and after thorough mixing, a drop of the corpuscle suspension is placed in the chamber, a cover glass applied, and the average obtained by counting a considerable number of squares and the necessary calculations made.

It will be obvious that errors cannot be avoided in dealing with such small quantities where dilution and a number of factors are used in reaching the total by multiplication. Accuracy in apparatus therefore becomes essential.

Previous to the war the finest haemacytometers were imported and soon after the great need for these pieces of apparatus for the American Army became manifest, the interest of Mr. Levy, well-known as the producer of accurate screens for photographic engravings, was aroused in the possibility of contributing to the winning of the war in this manner. Mr. Levy was interested only in case he could so greatly improve the haemacytometer that no one would be tempted to try further improvements for a number of years, and the results he obtained would seem to fit those specifications.

This haemacytometer is now made exclusively in America, and is far more accurate than those formerly imported. For example, cementing the engraved or photographic counting chamber upon the slide has been eliminated so that accuracy in the depth of the cell can be secured for the first time. By devising a parallel form of cell in place of the earlier circular ones, the effect of atmospheric pressure has been eliminated, and this was a source of considerable error in the circular chambers. In the new form a more even distribution of the corpuscles over the ruled area can be obtained, and of course the parallel form of cell is much easier to clean. By a clever use of glass of different refractive indices, the visibility of the ruling has been greatly increased in chambers filled with solution.

No one examining this American standard haemacytometer under the microscope can fail to recognize the skill displayed in etching these rulings. In one type the central square millimeter is divided into one-four-hundredth square millimeter areas, with an extra line in every fifth square for convenience in counting red corpuscles. The eight surrounding square millimeters are each divided into sixteen small squares for accuracy and convenience in counting the white corpuscles. Notwithstanding the necessity of working within such narrow limits, the intersections of these rulings are perfect and the manner in which all the lines are cut never fails to provoke admiration.

In determining the limits within which these counting chambers should be manufactured, a great many of those in use were examined, and errors amounting to as much as sixteen per cent were found in the depth of the chambers. This is

obviously so great as to invalidate the count in many instances, and it was to eliminate this possible source of error that the new construction above mentioned was devised. Thanks to coöperation on the part of the Bureau of Standards, tolerations have now been established and haemacytometers may be obtained with certificates indicating the maximum errors in the dimensions of the ruled spaces and in the depth of the chamber. Equal attention has been paid to the necessary cover glasses, so that all in all we may count the American standard haemacytometer among those results of the war which will prove of permanent benefit.

PROBLEMS IN ALLOYS.

In considering the possibility for coöperative research upon alloys, the Divisions of Research Extension and of Engineering of the National Research Council have obtained suggestions from a number of leading metallurgists concerning those problems involving fundamental research which might be taken up with a certain profit to those both using and producing alloys. Among these problems, the following may be mentioned as indicating the scope of the field and the opportunities which it presents.

There is need for further work on corrosion, including the action of commercial acids and other solutions used in industry, as well as that of the atmosphere, sea water, and other substances commonly considered in such studies. This has a bearing upon such articles as conduits, containers, lead for suphuric acid chambers, roofing, and boiler tubing. We cannot expect as rapid advance as is desirable in new alloys until more is known concerning the physical and chemical properties of both pure metals and their alloys. Closely related with this is the effect of traces or small percentages of elements usually regarded as impurities upon the properties of metals. Another phase might be designated as comparative metal technology, which would include a careful comparison of mechanical properties, as well as of general physical and chemical characteristics. The desirability of a study of deoxidizers and fluxes to be used in the preparation of non-ferrous metals is obvious, and there has long been needed a satisfactory test for machinability. Other needed tests are those which can be applied without destroying the article to be tested, as for example, the magnetic tests for the location of imperfections which are now being studied by a Committee of the Division of Engineering.

In tempering work with steel we need a comparative study of water quenching and oil quenching. What is the influence of forging methods on the fibre of metals, for we often find material of the correct composition which fails after having been subjected to forging? The relative effects and the life of different bearing metals should be determined, as well as the effect of inclusions in causing decarbonized streaks in laminated structures.

Throughout metallurgical operations a closer study of temperatures might prove advantageous, especially in the case of pouring. This brings up the question of molding sands and core sands, which still need to be studied in a comprehensive way. There is a vast amount of work to be done in completing the pubished data on standard alloys, in which should be tabulated their uses, composition, tolerance in composition, physical properties, their variance with differences in composition and with impurities. There should be a similar listing and testing of the non-standard alloys for the purpose of determining whether they may not be made standards themselves or acceptable substitutes for present standards, as prices change.

The subject of heat treatment naturally comes to the forefront and it would be desirable to develop an iron as noncorrosive as the present high silicon irons but with a more satisfactory degree of machinability. The composition of dies with reference to the service they must give in die-casting with present and new alloys should be undertaken. The malleable iron field presents its own peculiar group of problems, among which may be mentioned the development of a test which would truly indicate the malleable and shock-resisting qualities of malleable cast iron.

Perhaps the most pressing need is the thorough, indexing, abstracting, and classification of all published information on pure metals and alloys. This work would bring out the state of the art, from which would be brought to light groups of new problems, experiments upon which further work is required, and lines along which new effort could be directed for the purpose of checking conflicting evidence and repeating any necessary experiments. The information obtained would form an excellent basis for monographs on many classes of metals, such as the preparation of alloy steels at ordinary temperatures with various heat treatments, and at temperatures exceeding those found under normal atmospheric conditions.

This is but an incomplete list of the problems that have been suggested and from the entire list a few will be chosen for immediate work as a program upon which to solicit the support of the industries to be benefited. As in all research work, the solution of a problem at once suggests a number of others which would not have come into view excepting through the work accomplished.

HOME-MADE SYRUP FROM SUGAR BEETS.

Growing out of the efforts that have been made to utilize home-grown sugar beets as a source of culinary and table syrup, has come research to determine the substances which cause the undesirable flavor noted by some authors, in the hope that ways could be found to eliminate them. In the February number of the *Journal of Industrial and Engineering Chemistry*, Messrs. Ort and Withrow report their findings in an investigation, the object of which was to remove the undesirable flavor without injuring the sugar. Obviously the separation of the sugar as such would be out of the question, either in the kitchen or on the farm, and so was not considered.

In the article mention is made of the opinion held by many beet sugar men that the simple concentration of beet juice is sure to produce a syrup of objectionable flavor and odor, and that notwithstanding the work carried on intermittently during the last fifty years, none of the processes proposed has been of any value in improving these simple syrups. The directions given by the U. S. Department of Agriculture for the preparation of home-made syrups from beets do not result in very satisfactory materials according to the reports of many farmers, and in those cases the improper topping of the beets was described as the cause of the difficulty.

The authors describe their experimental work upon beets grown in Ohio in which a great many attempts were made to eliminate or destroy the undesirable flavor. These include clarification with milk, previous desiccation to coagulate the albumen, treatment with lime, peeling, coreing and treatment with such materials as fuller's earth, tannic acid, bleaching powder, and bone black. Variations of the temperature of extraction were also tried and in the end it was found that the best results could be obtained from beets from which the green shoulders, representing the portions which had protruded above the ground, had been removed by peeling. While this point was not definitely settled, it was found that syrup made from these green portions possessed the undesirable flavor to a very great degree and was quite dark in color, whereas a good syrup with but a trace of beet flavor and sometimes with no such flavor, could be obtained from beets prepared in the manner described.

The conclusions which will interest those who may be considering growing some sugar beets for their own use the coming season are summed up as follows: "The various published processes for making palatable sugar beet syrup do not consistently fulfill all claims made for them.

"The use of copper kettles is undesirable since it gives a metallic taste to the syrup. Enamel and aluminum ware are satisfactory.

"The process of skimming will not in itself eliminate the objectionable beet flavor.

"The peculiar flavor can be practically eliminated from sugar beet syrup by a proper attention to topping, paring off green portions, and brief preliminary extraction. The entire absence of green portions is necessary to good flavor.

"The objectionable beet flavor may be due partly to immaturity. Preliminary storage of beets will improve the flavor."

The chemical compounds which are responsible for the objectionable flavor have not been definitely identified.

PROCESS FOR SEPARATING LEAD SULPHIDE FROM MIXED ORES.

THE Bulletin of the Canadian Mining Institute states that the Elmore process for the extraction and separaton of lead sulphide from such mixed ores as occur in the Burma mines is based upon the following:

"When a mixtures of lead and zinc sulphides is treated with concentrated sulphuric acid at 100° C. under proper conditions as regards fineness, proportion, time of contact, etc., the lead sulphide is converted into sulphate, while the zinc sulphide remains practically unaffected. If the product is then washed in hot strong brine, the lead sulphate is dissolved and can then be separated from the undissolved zinc sulphide by filtration, etc. By cooling the hot brine, the lead sulphate is precipitated except for the amount that the cool brine will keep in solution, and the brine can then be reheated and used again. The details of course vary for different ores and there are other methods for handling sulphur dioxide, sulphonated hydrogen, or free sulphur liberated during the treatment."

LEAD PENCILS.

THE announcement that the western juniper has been found satisfactory as a source of slats for lead pencils recalls some of the work that has been done in an effort to find ways of producing red wood for pencil needs. The famous Tennessee cedar has long been the source of our pencil wood, but that is practically exhausted. Americans especially have come to prefer pencils the wood of which has a reddish color, and at one time a moderate-sized plant was successfully conducted with profit in the business of impregnating white cedar with dyes to produce a red shade. The pencil slats were put into a vacuum apparatus where the moisture was gradually withdrawn from them. While still under a vacuum a solution of dye was admitted and a condition from vacuum to pressure gradually brought about. At the conclusion of this treatment the wood was withdrawn, the excess dye liquor removed, and the material dried. In this manner the whim of the customer was gratified.

It seems that the juniper is also a reddish wood and that for several years the southern juniper has been used to piece out the Tennessee cedar. Even fence rails and posts have been called into service in meeting this need.

It appears that the wood of the juniper is reddish-brown in color and that in a majority of trees a bolt of wood six to eight feet in length, can be secured free of limbs. The tree has no tap root and frequently the largest trees can be pulled over by a team of horses.

SULPHUR VS. PYRITE.

FOR many years Spanish pyrite has been the preferred source of sulphur in the manufacture of sulphuric acid, due to the value of the by-products, and to the low rate of transportation which applied in bringing it to our country. Changed conditions since the war appear to be bringing about the substitution of sulphur for the pyrite for such purposes. There is a saving in the labor which must be expended in the mining, transportation, and handling of the pyrite and with increased wages, this has become a controlling factor. Trans-Atlantic transportation is also much more expensive than formerly. The sulphur mining operations in Texas and Louisiana have reached the point where pure sulphur can be sold in competition with pyrite and now that new deposits have been opened up and the Louisiana mines appear to be producing without signs of exhaustion, the sulphur companies are preparing to compete for the custom which heretofore has gone to lower grade material. These companies made large investments in order to supply the sulphur necessary for acid demand for war activities, and their decision to seek markets heretofore held by pyrite may be due to a desire to earn a return on invested capital.

THE SOUTHERN FOREST CONGRESS.

A NUMBER of conferences are being held composed of foresters and the various lumber and timber interests, to discuss our timber situation and the possibility of formulating a national forest policy which will ensure suitable supplies of timber in years to come. The Southern Forest Congress was held, beginning January 28th, in New Orleans, and they brought out the necessity of not only discussing the situation that all may be informed, but of actually doing something. The importance of reforestration, especially of those cut-over lands not suitable for agricultural purposes, was outlined with reference to agriculture, to naval stores, to the pulp and paper industry, to stock raising, and to the miscellaneous transportation and public interests of the community. The diversity of uses which chemistry makes of cellulose, one of the cheapest forms of which is wood, has been the subject of frequent discussions, so that the chemist is interested in the continuation of this comparatively inexpensive raw material. We have been taught for so long that our forest resources are inexhaustible, that many find it hard to believe that under present methods practically all of the merchantable timber will have been cut out of the south within fifteen or twenty years. In a few instances reforestration, either by the self-perpetuation of the forest or by setting out trees, has been undertaken, and at least one corporation is convinced that proper grazing methods will enable the cost of reforestration to be met by the sale of cattle. Four acres of cut-over pine land will maintain a steer for nine months and heavy grazing is essential for the removal of sage grass which is detrimental to the young forest. In the olden days in the west it was estimated that from sixteen to twenty-five acres were required per head of cattle, so it seems evident that the stock can be fed in the open areas or on dry feed for the remaining three months of the year and still leave a handsome profit.

A tract of cut-over land which is being employed for the production of a second forest is expected to be worth $450,000 sixty years from now and to produce a sum sufficient to meet taxes, over head, and seven per cent interest upon the investment meanwhile. This income will be derived from live stock operations and the sale of various classes of sticks, posts, and poles removed in the course of the necessary thinning.

It seems that only two advances have been made in the turpentine industry in the last 300 years. One of these was the adoption of the gutter and cup method for the tapping of the trees, and the other the substitution of copper for iron stills in the plants. Some valuable work has been done in Florida on problems in the turpentine industry, but there is obviously a great opportunity for coöperative research.

The Forest Congress adopted resolutions condemning wasteful practices, the approval of the plan to establish two forestry experiment stations in the South, and the setting up of nonpolitical state forestry departments in different states, with adequate appropriations to carry out a sustained program of useful work. The necessity of devising special tax laws for lands to be devoted to reforestration was recognized, as well as a more careful study of methods of taxing timber lands, based upon the yields of timber, and the separation of land values from timber values.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

STANDARDS OF GAS SERVICE.

For some years the Bureau has actively coöperated with the gas industries in various sections of the country. During the war, this assistance frequently took the form of extensive surveys of conditions existing in various cities and towns, with a view to regulating the gas industry so as to bring about the necessary alterations in service imposed by war conditions with the least hardship to the gas companies and the public.

In 1915, the Bureau issued its circular No. 32—"Standards for Gas Service" which may be said to have been the recognized authority in this country on the subject since that date. However, in the four years that have intervened since the circular was issued, fundamental changes have taken place in the gas industry. The use of gas for cooking and in industrial appliances has greatly increased, while its use in open flame burners, for purposes of illumination, has much diminished. Likewise developments have taken place in gas-making processes and changes have come about in the quality of gas-making materials available, and the general alteration of economic conditions brought about in part through the war have introduced new factors which ought to be considered in any publication treating on the subject.

To meet these new conditions, the Bureau has entirely rewritten a considerable portion of this circular and the work would have been pushed to a conclusion some time ago had not certain of the war activities prevented its active prosecution. The new edition, which will soon be completed, will contain sections on the heating value of gas, its freedom from impurities, allowable gas pressure variations, gas meters and meter testing, general service requirements, enforcement of regulations regarding service, a form for service rules for use by regulating authorities, a discussion of present methods of manufacturing and distributing gas, as well as certain data which it is believed will be useful to those persons interested in gas-making and using.

The revised manuscript of this circular has been completed and will be brought up for consideration and discussion in the near future at a meeting of the Represenattive Committee of Gas Engineers. This committee has been formed from the leading gas engineers of the country and on it the Bureau of Standards is represented. In this way, those particularly interested in the manufacturing side of the proposition, as well as those best able to judge of the scientific side of the problem as a whole, will be able to go over the material contained in the article. After the suggestions and comments of the members of the committee have been given consideration, the circular will be completed and printed for distribution.

CONFERENCE ON INDUSTRIAL SAFETY CODES HELD AT THE BUREAU OF STANDARDS ON DEC. 8, 1919.

The importance of standardization in safety work has been given a great deal of consideration of late, and in this work the Bureau has taken a leading part. It would appear undeniable that uniform regulation of industrial plants, from the point of view of safety, should be undertaken at once.

On December 8, 1919, a conference on Industrial Safety Codes was held at the Bureau of Standards and methods were discussed for developing a series of National Industrial Safety Codes, and for their introduction into use. It is the Bureau's desire to secure general coöperation in the preparation of these standards by those who will be most concerned with their application. Work of this sort to be effective must be participated in by all the interested parties, and the efforts of all concerned must be properly coördinated in order to insure that the set of codes drawn up will be applied uniformly in the different sections of the country.

An important result of the conference was the arrangement for a Joint Safety Code Committee on which the Bureau will be represented to recommend a list of codes which should have first attention, as well as the most suitable organizations for carrying out their compilation. The general sentiment, as recorded by a vote at the conference, is in favor of having the Bureau, in coöperation with the engineering societies and other bodies prepare standards in accordance with the methods of procedure of the American Engineering Standards Committee, and submit the resulting codes for the approval of that committee, in order to secure their general acceptance and use.

The Bureau is at present engaged in revising the National Electrical Safety Code, which was published in 1916, and it is hoped to issue a new edition within a few months. During December a draft of the code for Head and Eye Protection was issued and circulated among those interested, for criticism. The work on this code is practically completed and it is hoped to print the first edition in the near future. The work of preparing the National Elevator Safety Code, in coöperation with the American Society of Mechanical Engineers, is nearly completed and a final draft was prepared before the end of last year. It is now awaiting the approval of the committee which has had it in charge, the General Advisory Committee on Safety Codes.

STRAIN GAGE TESTS OF INDETERMINATE STEEL STRUCTURES.

In previous notes, the system of taking strain gage measurements of reinforced concrete and tile structures was described. A similar method has been used in calculating the stresses in statically indeterminate steel structures. A prominent example of work of this kind recently undertaken by the Bureau is furnished in the elaborate strain gage investigation of the large fitting-out crane at the Philadelphia Navy Yard, the tests of which were completed last December. This crane has a capacity of 350 gross tons and is probably the largest in the world. Strain gage readings were taken on all the important members and the work was carried through to a successful completion despite adverse weather conditions. A similar investigation was made nearly two years ago on a revolving floating crane at Norfolk. The accurate determination of the stresses in such structures is a matter of greatest importance from the point of view of the designer and will permit the construction of such cranes with every assurance of their success in service.

VELOCITY OF FLAME PROPAGATION IN THE CYLINDER OF A GASOLINE ENGINE.

For many years automotive engineers have discussed the probable velocity of the flame in the compressed and burning gas in the cylinder of an internal combustion engine. Many have maintained that this velocity was comparatively low and that in a high speed engine, in order to obtain maximum efficiency and power, at least two spark plugs must be used. It has been maintained by these engineers that by igniting the mixture at two points in the cylinder, the necessary time for complete combustion would be greatly reduced as com-

pared with that needed when but one spark plug is used. However, until very recently, no measurements have been made in an actual engine and the determination of this velocity has always been considered to present extreme difficulties.

For several months, the Bureau of Standards has been investigating this subject. A single cylinder gasoline engine, the combustion space, valves, piston, etc., of which are identical with those used on the Liberty aircraft engine, has been employed in this work. Three spark plugs are placed in the cylinder; the first is used to ignite the charge and is connected to the regular ignition system of the engine, the other two plugs are connected at approximately the proper time to a source of direct current, the voltage of which is insufficient to break down the gap between the sparking points of the plugs while under comparison, but which is sufficient to cause a spark to pass as soon as ionization of the gap occurs due to combustion of the surrounding mixture. These spark plugs are so connected with an oscillograph that the time when the flame reaches them is recorded on a strip of photographic film. The distance between the plugs is accurately known and the speed of the oscillograph film is also easily determined. It is obvious, therefore, that by measuring the distance between the points on the film indicating discharge of current across the gaps, the average speed of the flame between these points may be measured.

Determinations have been made of the velocity of flame propagation under many conditions of fuel-to-air mixture ratio, compression, speed, etc. The velocity appears to vary greatly under different conditions and to increase as the flame spreads through the combustion space.

THE PARACHUTE'S WORST ENEMY.

By E. R. Calthrop.

The standard patterns of all its smaller military aeroplanes —the single and two-seater—adopted by the British Air Service, carry behind them a tail-skid that amounts to a gaff or fish-hook perfectly adapted for the express purpose of catching and tearing the top of a silk parachute body when, issuing in a flash from its container, it instantly takes on the speed of the air current and is swept under the fuselage to far beyond the tail in less than a second. True that in the great majority of cases the apex of the parachute body whips past the tail-skid with a sufficient margin of space to give ample clearance; but, in the churning cone of compressed air, shot rearwards by the propeller, and outracing the speed of the air current itself, there are whirlpools of boiling air which can play strange freaks with a material so gossamery and non-resistant as silk. A vertical air-whirl can suck up the top of the silk body right into the tail-skid, even when the airplane is flying on a level.

If at the instant of the parachutist's jump the tail of the aeroplane is accidentally lowered, instead of being elevated, as should always be the case for a demonstration drop, there is grave risk of the tail-skid dipping right down into the path to be traversed by the body, and ripping such a long slit in the silk panels as to increase the rate of the fall of the parachutist to a speed that is dangerous. The resistance of the parachute is obtained by the continuous gathering up and compression of air within the body, and its subsequent centrifugal frictional dispersion from the edge of the periphery. Once a rent is started in the body, the contained compressed air forces itself through it, widening it out, and the tearing of the silk is continued until stopped by the reinforced edges of the panel. If this reinforcement is also cut by the tail-skid the tear will extend to yet another panel, which will further increase the speed of the dropping parachute; the increased speed will augment the pressure of the enclosed air tearing through the rent, and as the hole widens the leverage is greater for further destruction. If more reinforcements are burst only a miracle can prevent a fatal accident. Such a miracle has happened, but we cannot depend upon a continuance of miracles.

An aeroplane man-dropping parachute has to be designed to be of the least possible weight compatible with absolute reliability in its functioning, and an area of spread sufficient to cover the weight of the heaviest user, and to give, in addition. a safe margin for those abnormal happenings in the air—such as down dunts and the furling of the periphery—of which we are only at the beginning of learning some of the secrets. The epicycloidal section of the body, as now designed, has had the combined objects of (a) using the smallest amount of silk —reducing cost and weight—to attain the desired resistance and carrying power, and (b) of equalizing the stresses on the silk so that every square foot of the body area is carrying an equal load. The silk has to be sufficiently strong to meet normal and abnormal stresses, and the seams of the panels in the body have to be so designed that they act as reinforcements in the transference of the resistance from the body to the rigging and thence to the load—the parachutist. It is in the delicate balancing of all these strengths and resistances that saving of weight has gradually been gained without loss of strength, or of speed and efficiency in functioning, of nearly ten pounds. The safety of the parachute and of the parachutist depends upon the delivery intact and the sure full expansion above him of this filmy silk dome. Is it reasonable that work of this delicacy should run the risk of being ploughed through by the shear of a tail-skid? When a parachute body is gashed in this manner, it is not due to a failure of the parachute to function. It is purely extraneous happening, quite outside of the action of the parachute, which can easily be avoided.

There is no necessity whatever for a tail-skid to take the shape of a gaff, or that there should be any projections at the tail of an airplane that could rip a silk body. There are many airplanes already in existence in which the tail-skid presents a smooth unbroken outline, continuous with the under profile of the fuselage, against which the silk body could be thrown up by an air eddy without the least risk of a tear occurring. In the same way there are many machines now existing with tail planes not set at right angles to the centre line of the fuselage, as is the case with so many British machines, but sloping to the rear at an acute angle, so that if the leading edge is struck by the top of a parachute body it could not lap over the aerofoil and run the risk of a breakage, but would be harmlessly deflected out of the way. With all obstructing projections behind the cockpit smoothed away, a parachutist, would always get safely away.

It is for the Technical Department of the Air Ministry to point the way. They have full control of the designs and specifications of all military machines, and what they order has to be carried out. If they lay down the law that behind the cockpits there shall be no projections or rugosities that can possibly in any circumstances arrest or tear a parachute on its release from its container, fire, breakages, and loss of control in the air will be met without trepidation, for the pilot will know that in the last resort there will be no difficulty oin getting away from his machine safely.—From *Aeronautics*.

MOISTURE CONTENT OF WOOD

Even after long exposure to the same atmospheric conditions, different pieces of wood do not have exactly the same moisture content. Variations of 2 per cent were recently found in red oak blocks stored under carefully fixed humidity conditions at the Forest Products Laboratory.

These moisture differences, unlike variations in strength, are apparently independent of the density of the pieces. In the laboratory experiments, the variation proved to be as great in blocks of the same density as it was throughout the lot of specimens. Moreover, the range in moisture content was the same in wood of low density as in wood of medium density or high density.

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THE BALLISTICS OF VOLCANOES—ERUPTION OF SAKURA-JIMA, JAPAN. (SEE PAGE 292)

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THE MYSTERY OF MAYONNAISE.

THERE is no operation of the cuisine that causes the young housewife more apprehension than that of making mayonnaise. She may follow cook book instructions with utmost fidelity, and yet fail. She may do the work under the very eyes of an expert with no better results. There seems to be something uncanny about it. It calls for a mysterious something that cannot be acquired from printed directions or even personal instructions; and yet those who have the knack of making mayonnaise can produce it repeatedly without failure. They seem absolutely unconcerned and even careless in the way in which they mix the ingredients. We know of certain skilled chefs who do the stirring with the hand instead of a fork.

A light is thrown on the mystery of the operation by Professor Bancroft's article on "Bubbles, Drops and Grains," which appears on another page. The chemist recognizes mayonnaise as merely an emulsion of oil in water—a structure of microscopic drops of olive oil, coated with a thin film of white of egg and suspended in water.

The problem of making emulsions successfully has given trouble not only to the housewife, but to the pharmacist as well. Recently, however, manufacturing chemists have devised machines for producing emulsions. At first it was thought that it was merely necessary to agitate a mixture of oil and water in the presence of some colloidal agent in order to produce an emulsion. But when shaking machines were devised for this purpose they failed to produce emulsions. Then it was discovered that the shaking must not be continuous. It is necessary to give the mix a short period of rest, after which a little further shaking forms a successful emulsion. This throws a light on the mayonnaise problem. The usual directions are to add the oil drop by drop which usually results in frequent interruptions of the stirring, which is just what is needed in order to produce a successful emulsion. There are some experts, however, who will mix all the ingredients together and beat them up, after which they will let the material stand for awhile and then with a few strokes of the fork turn it into a successful mayonnaise. The mystery then of making mayonnaise is apparently psychological. The novice approaches the task with fear and trembling and does the work nervously, whereas the expert is much more leisurely and unconsciously puts in the necessary periods of rest.

While Dr. Bancroft does not claim to have tried out this theory himself, he offers it as a probable solution of the mystery. The problem which confronts the housewife is certainly similar to if not the same as that which has confronted the pharmacists and the manufacturing chemist. If this indeed be the solution of the mayonnaise mystery it furnishes us with another example of the far-reaching influences of scientific research.

PROJECTILES *FROM* THE MOON.

POPULAR interest in Dr. Goddard's rocket for reaching high altitudes were excited by the claim that this projectile could actually be made to travel to the moon and there flash a signal which would show that it had completed its journey. There is something romantic in the thought of crossing the intervening hundreds of thousands of miles to the faithful satellite that is our only close companion in the infinite reaches of space. To be sure there would be little if any astronomical value in such an accomplishment. It would serve merely as a demonstration of the power of man to overcome seemingly insurmountable handicaps. But interesting as the feat would be from this point of view, would we be doing anything more than the moon has been doing for millions of years.

According to Emile Bélot, Chief Engineer of Manufactures under the French Government, whose article appears on the following page, the meteorites which bombard the earth are projectiles shot from the moon. The formation of the moon's surface with its enormous yawning craters has given rise to many theories, but M. Bélot clings to the theory that they are of volcanic origin. He is an authority on the subject, having made a careful study of terrestrial volcanoes and the conditions which produce them. To demonstrate his theories he has constructed a working model of a volcanic region with which he is actually able to produce volcanic eruptions on a miniature scale. His model also throws light upon the peculiar crater formations of the moon which differ from those on the earth mainly in degree. He theorizes on the vast lunar eruption and the enormous amount of material they must have ejected. Owing to the lower gravity of the moon and its absence of any atmosphere, this material was hurled far out into space and might easily have escaped from the moon's attraction. It is these particles or volcanic projectiles, according to M. Bélot, which the earth encounters in its swing around the sun, and which fall to our surface as meteorites. These are not to be confused with the "shooting stars" and the meteoric showers which follow the orbits of comets and undoubtedly are of comet origin. He shows that meteorites are not of terrestrial origin and might have come either from our own moon or from the satellites of other planets. If we could identify them they would tell a wonderful story. Imagine the interest in a collection of actual samples of the substance of the satellites ranging from our own moon to distant Triton, the satellite that swings around the remote planet Neptune!

While we may some day be able to send samples of our handicraft to neighboring satellites, it is possible that these satellites have long been sending us samples of themselves. After all our isolation in space may not be quite so real as we had imagined it.

The Ballistics of Volcanoes*

Volcanic Action in the Earth, the Moon, the Universe, and the Laboratory

By Émile Belot, Chief Engineer of Mauufactures under the French Government

THIS time a year ago the big Berthas were circling the Sorbonne with their shells, striking now at the temples of Heaven and now at those of Science. Today, their proud heads are diminished and I mention them but to serve as an introduction to the vast subject of volcanic action, whose extent is far from being generally known or even suspected; there is a victory of mind over matter in the very fact that this colossal engine of scientific barbarism can thus be made to assist in the perfecting of our knowledge in the peaceful domain of Science.

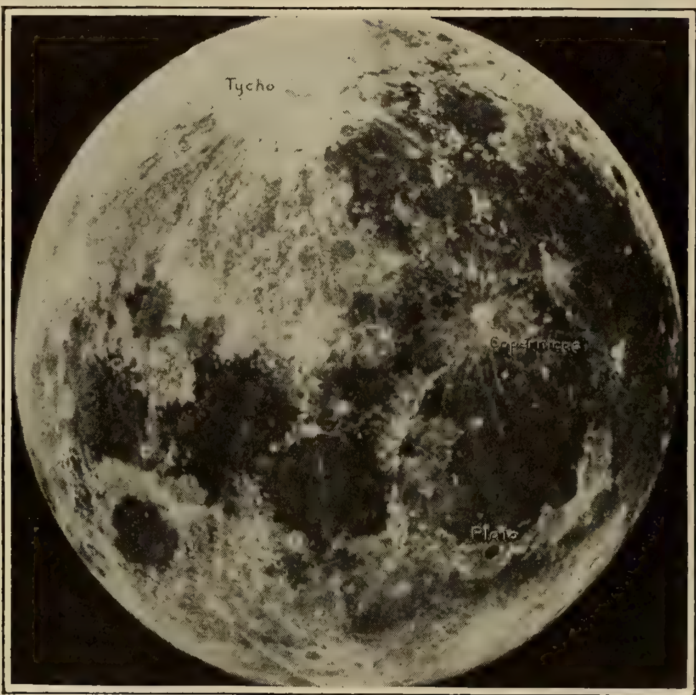
What then is the nature of a "super-gun"? It is a gigantic tube directed towards the sky just as are the volcanic chimneys of volcanoes. At the base of the tube, inside the bore of the cannon, the deflagration of the powder imparts to the gases and vapors a pressure of several thousand atmospheres; in the same way at the base of volcanic chimneys the internal heat of the earth imparts to various fluids a formidable expulsive power. At the instant when the gun is fired there issues from its mouth extending to a short distance a banner of smoke and flame, while the shell is shot to a great distance because of its great density and of its carefully designed form. Likewise when a volcano explodes there is seen a column of smoke and fire from which there are projected volcanic bombs and fragments of rock. The colmun of fumes which rose from the crater of Krakatoa was projected to a height of 27 km., but as a general thing the explosive smoke plumes of volcanoes are not more than 8 or 10 km. high. Thus we see that if there is a resemblance between the form of the super-gun and the volcano there is even more similarity not to say identity of action between them.

Let us now examine a pecularity with respect to the firing of the Berthas, which was unfortunately of only too much service to our enemies, and which it is necessary to bear in mind in order to comprehend the wide extent of the volcanic domain. At a height of about 30 km. the shells of the big Berthas reached an atmospheric region where the pressure of 760 mm. which the mercury exhibits at the surface of the earth, is reduced to 1 mm. at the outside—this is as much as to say that the resistance of the air has practically ceased to exist, and the shell has no further trouble, fairly devouring space and lengthening its trajectory. Without this favorable circumstance our enemies would have found it difficult to reach Paris from a distance of 120 km.

The question of the possible range of volcanic bombs is governed by the same principle, and we shall first discuss the problem of the external balistics of volcanic products, and shall speak later of the internal ballistics, which are far more complicated, because they are the result of manifold actions within the bosom of the crust of the earth.

THE EXTERNAL BALLISTICS OF VOLCANOES.

Let us first inquire what becomes of the volcanic matters projected outside the volcano. The first thing they do is to erect the external volcanic cone, but all those volcanic matters which fall within the crater are projected anew, together with the walls of the crater, which thus forms a cup shaped opening. Upon our earth the craters of volcanoes are only a few hundred meters in depth, while upon the moon they are sometimes as much as 4 or 5 km. deep: upon the earth only three carters (Kamschatka, Japan, Philippine Islands) exist which are as much as 20 km. in diameter, while in general the diameter is less than 5 km.; the lake of lava upon Mt. Kilaue, Hawaii, is only 3,200 meters wide. Upon the moon, on the contrary, many craters are as much as 100 km. wide (Theophilus) and sometimes 150 km. (Petavus). We must first explain the reason for this great difference of dimensions upon the earth and upon the moon.



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THE FULL MOON. NOTE THE STREAKS RADIATING FROM TYCHO AND COPERNICUS

The great American astronomer, Pickering,[1] says upon this subject:

"Although the force of gravity upon the moon is capable of projecting the matter expelled to a distance six times as great as upon the earth, the theory of the production of craters by steam is practically abandoned—for it is now evident that this explanation is inadequate to explain the great difference of dimensions in craters observed."

But Pickering is mistaken. Being an astronomer he has borne in mind only the *astronomical factor, gravity,* which is in fact only one sixth as great upon the moon as upon the earth; but he has completely forgotten the *physical factor, i.e., the pressure of the atmosphere,* which is very great at the surface of the earth and nil upon the moon, since the latter has no atmosphere.

Let us try to set this difference in figures: A volcanic bomb projected upon the earth to a distance of 3 km. would attain upon the moon a distance six times as great, i.e., 18 km. because of the slight force of gravity upon the moon. Such bombs would be capable of erecting upon the moon the crest of a crater 36 km. in diameter, but not, however, a crater 100 to 150 km. in width. But upon the earth the range of a volcanic projectile is reduced to only 1/3 or 1/4 of its theoretical range in a vacuum; it is necessary, therefore, upon the moon to multiply by 3 or 4 the result given above because

*An address delivered March 30, 1919, at the Sorbonne, under the auspices of the Society of Friends of the University. Translated for the *Scientific American Monthly* from the *Revue Scientifique* (Paris).

[1] Pickering, Lunar and Hawaiian Physical Features Compared (1906).

ENORMOUS CRATERS ALONG THE LUNAR APPENINES AND ALPS

CRATER THEOPHILUS 64 MILES ACROSS AND 18,000 FEET DEEP

the lunar projectiles are launched in a vacuum. 3 x 36 = 108 km., 4 x 36 = 144 km. Thus we see that the theory is adequate to explain the matter when it is completed by the laws of physics, contrary to the opinion of Pickering.

Before we continue our examination of the volcanoes of the moon we must study an analogous problem upon the earth, namely: Is it possible for bombs shot from terrestrial volcanoes to escape into interplanetary space? The science of astronomy has demonstrated that because of the attraction of the earth, the rate of travel of these bombs ought to attain a speed of 11 km. at the extreme limit of our atmosphere, i.e., at a height of about 100 km., but the science of physics teaches us that because of the small mass and the irregular surface of those projectiles they ought to leave the surface with a speed of at least 30 km.[2] in order that the rate of speed remaining at a height of 100 km. shall be as much as 11 km. But measurements of projections occuring at Cotopaxi have given the rate as 2.5 km. per second; hence it appears to be quite certain that no terrestrial volcano has ever succeeded in projecting bombs with a velocity of 30 km.[3]

But what is quite impossible for the volcanoes upon our earth is possibly far more easy upon the moon and upon the volcanoes of satellites in general, for the reason that they have no atmosphere and that the force of gravitation upon them is very slight. And this brings us to a possible origin of meteorites and bolids; may they not be projectiles shot from the volcanoes of the moon or from all the volcanoes of all the satellites of the various stellar systems?

BOLIDS AAD METEORITES CORSIDERED AS BOMBS FROM THE VOLCANOES OF SATELLITES.

Meteories and bolids must not be confounded with the "shooting stars" of the periodoc swarms which are formed in the wake of the orbits of comets, as Schiaparelli has shown. It is the meteors exhibiting no periodicity, such as sporadic shooting stars, bolids and metorites, whose origin may be attributed to the volcanoes of satellites.

[2]The formulas employed by the naval artillery give (supposing it to be permissible to extend the extrapolation to these rates of speed) a speed which is inversely proportional (and that much nearer to 11 km.) to the diameter of the projectile. We assume here that the volcanic bombs have a maximum diameter of one meter, a maximum which is, however quite exceptional.

[3]While it is possible that the primitive volcanoes were more powerful than those of the present time, on the other hand they were surrounded by an atmosphere which was much more dense and, therefore, offered much greater resistance to their projectiles.

What then are the characteristic properties of meteorites? We know from the profound study of them made by Stanislas Meunier, that they are actual geological specimens of the earths of the Heavens and that *they have never been fused.*[4] This is one reason more for affirming the ballistic impossibility of the supposition that these stones could have come from terrestrial volcanoes. But there is still a third reason which excludes such an origin: All terrestrial rocks which like meteorites are very dense and which contain a high percentage of iron are strongly radio-active, whereas meteorites are not so at all. But all radio-active bodies have a very high atomic weight, hence it is natural to suppose that they are concentrated near the center of our system and that they are absent in the regions which are remote from the sun, in which regions furthermore those planets are found which are by far the lightest in weight. Thus the large satellites of these planets, which possess a mass and dimensions which approximate those of the moon, probably have, like the latter, volcanoes which are capable of launching projectiles into space—but which projectiles are not radio-active.

At this point we may be confronted by a serious objection, namely: How is it that the stones which occur in the Heavens can proceed from volcanoes if it be true that they have never been in a molten condition? To answer this it is necessary to extend the idea of the nature of volcanoes: Even upon the earth at the present time there exist chimneys or "necks" such as the diamond bearing chimneys of the Cape, wherein the rush of gas and vapors which escapes from them is filled with *non fused* substances. Another manifestation of what may be called merely hydrological volcanic action is found in geysers, which may be imitated furthermore in our laboratory experiments. Why then should it be considered astonishing that upon satellites where the internal heat has always been much less than upon the earth, the vapor and the gases have not been able to attain a temperature of more than 500° to 600°C., whereas the fusion of rocks requires from 1000° to 1200°C? Furthermore, upon these satellites as upon the moon, because of the low gravity which prevails the same internal pressure which operates in terrestrial volcanoes would suffice to project a column of non-fused rocks to six times as great a height—thus it is evident that the volcanoes of satellites are capable of producing the matter found in meteorites, both as to quality and as to quantity.

[4]It is only upon the surface that they are heated by the friction of our atmosphere so that they become coated with a black patina.

If it be added that the number of volcanoes upon the moon is estimated at 60,000, that each one of these has certainly undergone several eruptions, and finally, that there are a great many more satellites than there are planets, it can be readily understood why there is such an enormous number of volcanic bombs plowing their way through interplanetary space.

Let us now consider the aspect of the lunar volcanoes. These are better known to us in some respects than those of the Earth, since we possess photographs of them taken from aeroplanes (remarkable discoveries have recently been made by photographing volcanoes in Hawaii by means of kites). Upon the Moon Tycho is remarkable for its rectilinear, radial streaks, sometimes as much as 2,000 km. in length. These cannot be due to winds carrying along cinders and ashes, since there is no atmosphere; furthermore, the winds of the earth never have a rectilinear trajectory of such great length. These streaks are due, as we shall see, to direct projection of fragments of matter.

Other volcanoes, including Kepler and Copernicus also exhibit some of these streaks or trails but these are mainly quite visible streams of matter: A great many volcanoes exhibit several circular belts and central peaks from 2 to 5 km. in height, while the bottom of the craters is from 4 to 5 km. below the crest.

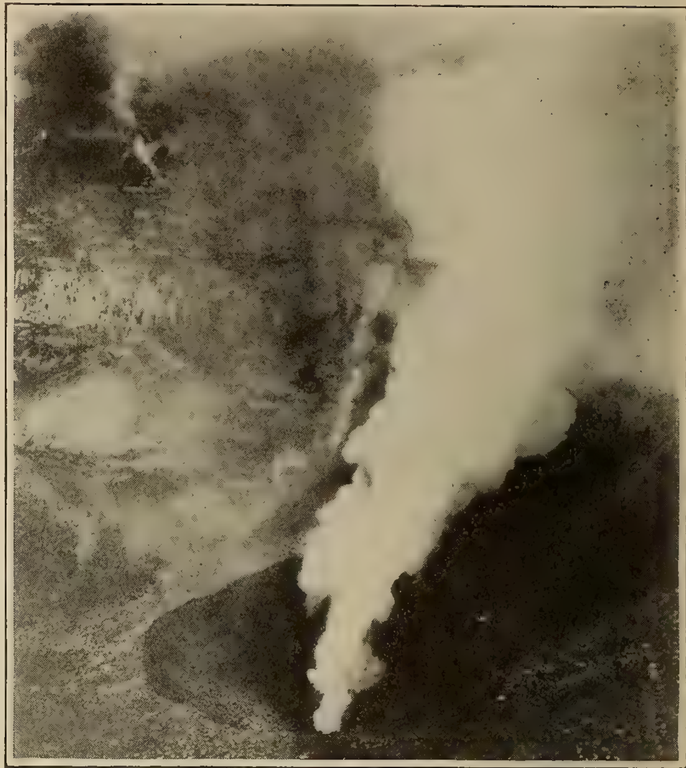
Let us suppose that at Paris, taken as a center, there should rise from the spot where the Eiffel tower now stands, one of the peaks of Sancy, and that a crest composed of juxtaposed Mount Blancs formed a circular belt, passing through Chartres, Vernon, Beauvais, Compiégne, Chateau-Thierry, and Fontainebleau; this would give us an idea of the formidable volcanic structures which have been erected upon the moon, because the physical forces thereon are so much superior to the forces of gravity, and it would be absolutely non-scientific to suppose that what has been proved possible upon the Moon does not occur upon the other large satellites of our system which have a similar mass or density.

THE COSMIC BALLASTICS OF VOLCANOES.

It remains to be demonstrated that the ballistics of volcanoes have been capable of projecting these missiles, not only to a distance of 2,000 km. upon the moon, as in the streaks of Tycho, but even into interplanetary and interstellar spaces. It is this which I have succeeded in doing as reported in

MAYON VOLCANO IN THE PHILIPPINE ISLANDS, 8,290 FEET HIGH

various notes to the Academy of Science[5] and to the Astronomical Society of France. I shall, therefore, merely state the results of these calculations. Upon the Moon a volcanic bomb projected with an initial speed of 500 m. per second, *i. e.*, the same as that of the shells thrown from our 75 mm. guns, in a direction forming an angle of 15 degrees with the vertical would ascend to a height of 70 km. and would fall at a distance of 75 km. Such projections would be capable, therefore, of erecting craters having a diameter of 150 km. If the initial speed is increased to 2 km., i.e., to a speed slightly less than that already observed in the projections from Mount



LOOKING DOWN INTO THE CRATER OF VESUVIUS

Cotopaxi, the range would be 1500 km.; in other words a distance equal to that from Paris to Lisbon and approximately as long as the streaks of Tycho.

Let us now consider a phenomenom of even greater grandeur whose actual occurrence the science of astronomy bears witness to, and which depends solely upon the value of the product of the radius of the moon by its density, i.e., by the weight at its surface: As soon as the rate of speed of projection of volcanic bombs attains 2250 m. these projectiles escape from the attraction of the Moon and become either satellites of the Earth or planets revolving around the Sun and in the same direction; whether the bombs become satellites or planets depends upon the direction of the trajectory with respect to the lunar orbit. These miniature planets of a new kind may even go far enough to intersect the orbit of Venus and that of Mars. Thus, the earth as well as Venus and Mars may receive in the form of bolids a rain of such bombs which escaped long, long ago from lunar volcanoes.

But it has been demonstrated by calculation that none of these bombs has either an orbit in the retrograde direction or a hyperbolic rate of speed: but investigations conducted in America by Professor H. A. Newton and in England by the Committee on Shooting Stars have established the fact that six out of every hundred meteors have a retrograde orbit, and that the rate of speed at which a shooting star strikes the earth quite frequently exceeds 72 km. per second and is sometimes even as much as 100 km. per second; in this case we are certainly concerned with the hyperbolic orbit, i.e., with a mass of matter which travelling along a curve which diverges infinitely, comes from a very great distance—or more probably even, from interstellar space into the solar system.

What is the origin then of meteors of this character? To answer this we have only to accept it as true that like the moon the great satellities of the other planets and especially of those which are very remote, also have their own volcanoes

[5]*Comptes Rendus* of the French Academy, April 25 and August 7th, 1916.

which are flooding space with their projectiles. I have made the calculation for Triton, a satellite of Neptune, and for Titania, a satellite of Uranus, and have proved that their volcanic projectiles are launched into space along orbits which may be either retrograde or hyperbolic as the case may be.

Thus we see that merely through the play of volcanic physical forces, it is possible for some of the solid matter of our system to escape from the attraction of the Sun and wander off to pay a visit to the neighboring stars. And by the same kind of mechanism the latter may also be able to send us geological messages substantially confirming what the spectroscope has already taught us, namely, the unity of the cosmic composition of the stellar universe.

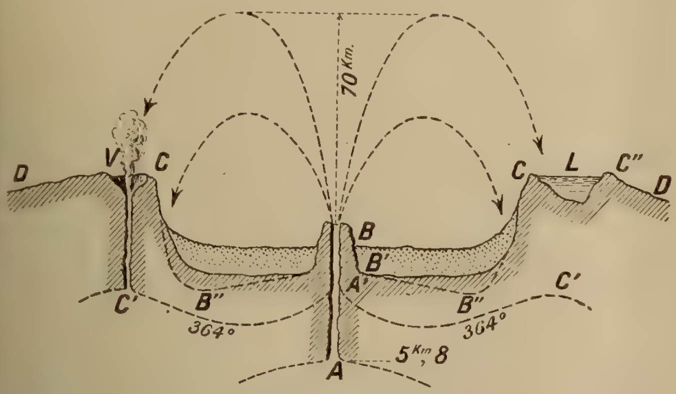


FIG. 1. MANNER IN WHICH A LUNAR CRATER IS FORMED

B, original level before eruption. Water descending into the crater erodes the entire thickness of material B B′ which the volcano hurls out building the crest C. B″ B′ B″ is the upper isothermal surface and C′ A′ C′ an isothermic surface of 364 degrees. The raising of this surface has formed small volcanoes along the edge of the crater (V, active; L, a crater lake). The hot center, 5.8 km. deep, furnishes enough pressure to hurl rocks to a height of 70 km. and over an area 150 to 200 km. in diameter.

It is clear that these researches are of the highest interest from the point of view of natural philosophy, since they result in giving us the novel ideas of an exchange of solid matter between stellar systems and of vacuous space powdered with dense volcanic dust, which may come from the very confines of the Milky Way.

But it is time to descend from these lofty heights once more to the earth—for if we now understand pretty well the external effects of volcanic action we still have to examine the nature of its internal mechanism, which is less easy to comprehend.

CHARACTERISTICS OF TERRESTRIAL VOLCANOES AND THEORIES OF VOLCANIC ACTIONS

Let us first seek to "understand the nature of volcanic action upon the Earth; a capital fact revealed by the statistics of Mercalli is of prime importance in this domain, namely, that out of 415 active or quiescent volcanoes there are 244 situated upon islands and 160 along the edges of the continent, while only 11 are found either in the center of Asia or of the Sahara desert remote from the oceans of the present time.

But in Central Asia there exist basins in the interior which do not communicate with the ocean and the Sahara has been frequently invaded by the sea. Another peculiarity which I believe I, myself, may claim to have been the first to point out is that volcanic action is strongly concentrated between the tropics, there being three volcanoes per unit of surface in the intertropical area of the earth, for one in all other regions from the poles to the tropics. This peculiarity bears a close relation to the equatorial precipitation of the last three zones of satellites of the earth, whose existence I have demonstrated, and which has given rise to the formation of chains of mountains by zones more or less close to the equator in our hemisphere. This fact must also be considered as being related to the remarkable concentration of solar spots between the latitudes + 30 degrees.

The localization of almost the entire number of volcanoes upon islands and along coasts at once suggests *the marine origin of volcanic action.* There are several theories such as those of Stanislas Meunier and of Armand Gautier which may contain a portion of the truth, but which entirely fail to explain this localization. The experiments made by Gautier are very suggestive: He has shown that granite porphyry, etc., pulverized and dried at about 100°C, liberate, when raised to a red heat, from 1 to 1.5 per cent of water vapor, together with certain gases (hydrogen, sulphuretted hydrogen, etc.), which are precisely those which issue from volcanoes. It is obvious, therefore, that it is only necessary for the internal heat of the earth to ascend into certain strata situated in the crust of the earth, in order to provoke volcanic phenomena. But how is it posible for the internal heat to approach the surface? Various objections have been proffered to the theory that the ocean is the origin of volcanic action.

Professor Brown of Geneva believes himself to have proved that volcanic action is anhydrous, but two objections have been raised against his theory: In the first place the manner in which he collected specimens of gases in active craters has been criticised, and secondly, his experiments fail to be convincing. He subjected pumice stones and clear peridots containing ferrous silicates to the action of steam at temperatures of from 750°C. to 1300°C. The ferrous silicates were altered in color to the black or red tint characteristic of ferric salts, thus indicating the oxidation of volcanic rocks under the action of water vapor at a high temperature. But it is a known fact, however, that, inversely, metallic oxides heated in a current of hydrogen may give up their oxygen and be reduced to a less highly oxidized condition. It is possible, therefore, that a current of hydrogen, mingled with the water vapor employed in Professor Brun's experiments, may have prevented by means of an inverse reaction the production of ferric oxide, and it is a well known fact that volcanoes give off hydrogen both in a free state and combined with sulphur and with carbon.

But even supposing for the sake of the argument that there were no trace of water vapor in the gases issuing from the volcanic chimney—this fact would in no way prove that water in the state of vapor is not the original motive power producing volcanic action. As a matter of fact, by virtue of the oxidation reaction established by Professor Brun, the

ONE OF THE MANY ACTIVE VOLCANOES IN JAPAN

water reduced to the state of vapor in the interior of the earth's crust might oxidize during its outward passage the basic rocks with which it came in contact, thus allowing hydrogen under pressure and at a high temperature to act upon the molten lava. Upon its issuance from the crater this hydrogen at a high temperature would combine with the oxygen of the air to produce the water vapor which is so abund-

antly found in the clouds accompanying volcanic explosions; the rocks projected outside would not have time to be appreciably oxidised during the few seconds required by their passage.

Thus chemical objections to the marine theory of volcanic action are of but little value. Let us see whether physical ob-

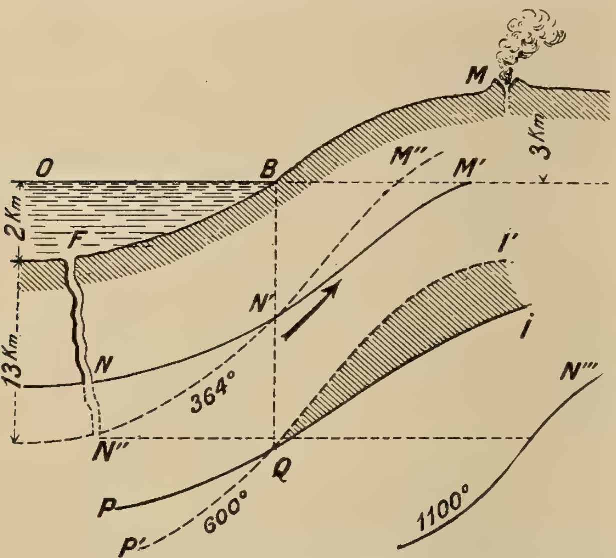


FIG. 2. DIAGRAM EXPLAINING THE ASCENT OF THE ISOTHERMAL SURFACES BENEATH THE CONTINENTS

NM′ = normal isotherm (364°C.); PI = isothermal surface in which the temperature is 600°C. The flowing of the water into the fissure FN lowers the isothermal surface (364°C.) at the point N′; the escape of the gases lifts the isothermal surface underneath the continent from M′ to M″. The other temperatures fall and rise under the same conditions. P descends to P′, I ascends to I′. The isothermal surface of 1100°C. is that of the fusion of the deep lying rocks which the water vapor issuing from the central boiler carries with it to the outside by way of the crater. OB = sea level; M = crater.

jections are worth more. It has been pointed out that numbers of volcanoes in the mountain chain of the Andes are situated at a distance of 200 km. from the sea, and that it is impossible to believe that there can be so long a subterranean inlet from the ocean. To this we may answer that the geologists are not at all afraid of assuming such a long inlet when they are trying to explain the existence of artesian wells. Thus, the artesian wells in the neighborhood of Paris are supposed to be fed by the water which filters through the green Aptien sands from the high valley of the river Aisne. Why, then, is it considered impossible that volcanic action may be produced by water from the ocean?

But, our objectors add, since the water of the ocean is of unlimited extent, if this theory be true when an eruption once began it would never stop. The geologists, who proffer this objection, simply forget that water in a state of vapor at a high temperature is a very energetic chemical agent, oxidising the rocks it comes in contact with, and that, moreover, ocean water contains 3.65 per cent of various haloid salts. The oxides formed and the salts remaining after the evaporation or decomposition of the water would be deposited in the subterranean aqueducts and would finally choke the mouths of these so that the volcanic action would be arrested, at least for a time.

But it may be asked how volcanic action, which has been progressively arrested after a convulsion, can be made to start up again? This is simply because the subterranean channels into which the salts were deposited at temperatures below 500°C. being no longer cooled by the deposit of the sea water would again rise in temperature up to 700 or 800°C., the temperature at which the mineral salts found in the sea are fused and volatilized. A fact which proves that things happen like this is that an eruption generally begins with dry fumeroles at a high temperature which contain chlorides chiefly.

Lastly, a final objection very widely found in books upon geology is to the following effect: If the water from the bottom of the ocean descends into the crust of the earth through fractures in the latter and is there reduced to steam, then the pressure of the latter ought to drive back the water through the passages whence it came. This objection proves that one may be a very good geologist and yet be ignorant of the physical laws governing water and boilers—here we have an example of the danger resulting from too narrowly dividing the sciences into separate compartments. But every engineer well understands that in any industrial boiler the path followed by the water when going to be vaporized is not the same as that followed by the steam when the latter is leaving the surfaces where it has been vaporized. Why then should water vapor in the terrestrial boiler be expected to follow a different law from that which controls it in the industrial boiler? And the said law is very simple, namely: *water follows the path imposed upon it by the laws of gravity whereas vapor follows the isothermal surfaces*, i.e., those surfaces where the temperature is sufficient to maintain it in the state of vapor.

NEW MARINE THEORY OF VOLCANIC ACTION.

The law stated above leads us directly to a very simple explanation of volcanic action and to the experiments which have enabled us to produce such action experimentally.

Let us first try to find out, therefore, what becomes of the ocean water which penetrates the crust of the earth through a fracture in the latter in the neighborhood of a steep coast line. At the bottom of the sea, which is at least 2,000 m. deep and which communicates freely with the polar region, the temperature is very close to zero (Centigrade). The same thing is true at the top of a mountain near the coast which rises to a height of 3,000 m. To find within the ground a temperature of 100°C. we must descend 3,000 m. inside the mountain as well as underneath the bottom of the ocean; in a word the lines or surfaces of equal temperature, *i. e.*, the isothermal lines or surfaces, will be very much inclined to-

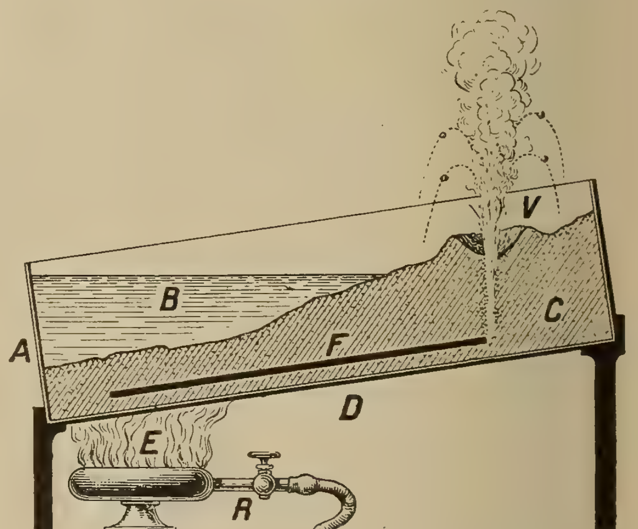


FIG. 3. THE EXPERIMENTAL BASIN DEVISED BY M. BELOT: SECTIONAL DIAGRAM

AD, tank of sheet metal; B, water; C, sand; F, slate; V, volcano; E, gas flame regulated by the stop-cock R. The heat of the flame E causes the water contained within the sand to come to the boiling point only where it is in contact with the bottom D. The steam escapes underneath the miniature continent forming a crater, while the water B remains cold.

wards the sea and the steeper the coast the greater the degree of this inclination. But because of the enormous pressure (200 atmospheres) which prevails at the bottom of the sea, the water which penetrates the fracture (Fig. 2) will not be turned into vapor at 100°C. and does not arrive at

this state until it reaches the isotherm of 365°C. at about 13 km. below the bottom of the ocean; in other words 365°C. is, as a matter of fact, the *critical temperature of the water*, so called *because of the fact that at that point water exists in the state of vapor no matter what the pressure may be.* The isothermal surface of 365°C. will be like all the others practically parallel to the external solid surface, *i. e.*, it will ascend towards the continent. Since the vapor is obliged to follow the isothermal surface it will, therefore, ascend along this surface towards the continent in place of trying to drive back the water in the fissure. The strata of the earth being cooled by the passage of the sea water, the isothermal surface will run downwards from N′ towards N″ beneath the ocean and through the calorific action of the vapors will ascend within the continent to M″ which will increase still more the slope of the isotherms. All of the isothermal surfaces already inclined will follow this see-saw motion which is favorable to the exit of gases and vapors from the continental surfaces. Thus we see that *volcanic action will begin by an eruption of gases and vapors*, contrary to the views of T. See and of Contejean, who are of the opinion that the marine theory indicates the immediate issuance of lavas under the supposition that the latter must be under pressure beneath the continent through the vapors produced in the bottom of the seas.

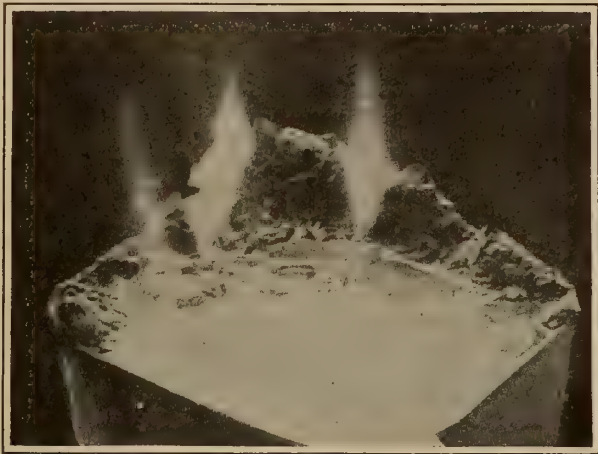
But it may be asked how the marine theory can explain the arrival of lavas at the surface when the temperature of fusion of rocks (cc. 1,000°C.) is in general not attained except at a depth of about 30 km. and when at the level N″ the weight of the salt water in the ocean and in the fissures is certainly not more than one-third as great as a column of lava of the same height and especially since such a column of lava sometimes rises as much as 3 km. above the level of the sea. We answer that this occurs through the same paradoxical process which, in industry, causes a column of hot water to rise to a height of 10 m. when subjected to a pressure of 1 m. of water only, or of 0.1 atmosphere; in the same way we have in the ascending column *an emulsion composed of vapor and hot water*, whose average density is much less than that of the water. If we assume that in its subterranean trajectory the vapor finds molten lava at the point N″ and a passage of exit in the vicinity of the apex of the continent M, then the two fluids, the vapor and the lava, will mingle at this point, the vapor having, because of the enormous pressure, a density close to the critical density 0.33, and the lava having a density of 2.7.

If the emulsion formed contains a volume of vapor four times as great as that of the lava, this is all that is necessary to cause the latter to make its appearance under a strong pressure at the point M, having ascended 3 km. above the sea level. This novel marine theory can be verified by experiment, at any rate within certain limits, in a laboratory. I have succeeded in reproducing all phenomena of volcanic action by endeavoring to produce in a shallow basin L. 60 m. by 0.60 m. an inclined isothermal surface D, heated beneath by a heater E (Fig. 2). For this purpose the basin A is filled with a argilaceous sand C representing a continent near the coast where the bottom is elevated, while the water B represents the sea. The sand is entirely permeable by the water, and if the theory accepted by so many geologists were true, we should expect to see the sand lifted by the vapor above the heater E—but this does not occur. The vapor follows the sloping ascent D and does not escape until it reaches the top of the slope, first forming fumeroles and causing at V projections of solid matter which forms a crater. If we interpose in the midst of the sand a horizontal stratum of red iron oxide, the latter in spite of its density will ascend within the volcanic chimney and be projected upon the miniature continent in the form of red volcanic bombs.

By these experiments we have produced the paradoxical phenomenon of a "volcanic V" at 100°C., while the "sea" above the heater is entirely cold. In order to reproduce the case which so frequently occurs in nature of impermeable strata, alternating with permeable strata we may place a slab of slate F a little above the bottom. In this manner we were able to obtain new effects, namely, multiple volcanoes, operating simultaneously and a race or bore. When the piece of slate touches the bottom D of the coast of the continent, we can also produce submarine volcanoes whose crest will gradually rise in a circular form above the level of the miniature sea.

A general view of the miniature basin which I have made use of to represent experimental volcanic action, shows in the center a crater-lake produced by the preceeding experiments, an eruption just beginning (at the right), and an ruption which is beginning to form its crater and is heaping up upon its external slopes a concretion of ejected matter (to the left); finally in front of the latter crater there is an extinct crater showing the orifice of its volcanic chimney.

The experiments described and the theory which suggested them lead us to the general conclusion that there is a subterranean connection between the volcanoes and the ocean, and that the vapors of the waters are directed towards the substructure of the continents by the inclination of the isothermal surfaces.



THE EXPERIMENTAL VOLCANO IN FULL OPERATION

In the center toward the front appears the crater-lake formed by a preceding experiment; to the right is shown a volcano in which the eruption is beginning; to the left at the rear is shown a volcano which has already formed its crater and covered its slopes with bombs; to the left in front is shown an eruption which is almost finished, the crater and the orifice of the volcanic chimney being visible.

The general law governing volcanic action may, therefore, be formulated as follows: *Volcanic action in relation to the water of the ocean is proportional to the steepness of the continental slopes and to their degree of convexity with respect to the ocean.* This law can at once be verified by the islands in the open seas, since these are nearly always volcanic in character because of the fact that the isothermal surfaces here form a cone which concentrates the vapors at its apex.

INTERNAL FRICTION IN THE ATMOSPHERE.

A recent German journal (Th. Hesselberg, *Annales der Hydrographic und Maritimen Meteorologie*, Part V.-VI., 1919), contains a discussion of the influence of internal friction on the relation of the surface wind to the pressure gradient. Much of the paper follows the lines of G. I. Taylor's paper of 1915. It is shown that certain pilot-balloon observations at Lindenberg agree with the theory that turbulence is independent of the height. The results make the eddy viscosity 4.2×10^4 cm²/sec. Attempts are made to deal with pressure gradients and eddy viscosities varying with the height; but these are vitiated, the first by an incorrect integration of the equations of motion, and the second by the use of a wrong form of these equations themselves.

Charting the Mind

Modern Apparatus Employed in Psycho-Physics

By T. A. Marchmay

AN entertaining story is told of a small girl who, after being sunk in a brown study for several minutes, suddenly exclaimed, "Why nobody knows what's inside of me, except what I tell them myself!" The anecdote is not only illustrative of the dawn of self-consciousness of the individual mind, but suggests likewise the dawn of self-consciousness in the race. At some point in man's upward progress he became conscious at once of his indwelling spirit and of the isolation of that spirit.

More and more through the long ascent of centuries man has been occupied with the problems of the nature and origin of his own spirit and with its relationship, not only to the body that houses it but to the spirits of other men, whether dead or living. But whether among savages, among the schoolmen of the middle ages, or among the metaphysicians of the 17th, 18th, and even the early 19th centuries, the spirit has always been considered as something esoteric, a thing fettered by the body and subject to temptation from the latter and yet something intrinsically apart.

It is not our intention here to enter upon any debate as to the true nature of the spirit of man. Whatever its nature, whatever its origin, whatever its destiny, it is, while an occupant of its earthly tabernacle, subject to approach only through the gateways of the senses. It is the comprehension of this fact which has fundamentally altered the methods employed in psychological study of recent years. In short, psychology has at last taken its rightful place among its sister sciences —those sciences whose insignia are the balance and the measuring rod. In the words of an eminent modern psychologist, Dr. John B. Watson, of Johns Hopkins University: "The key which will unlock the door of any other scientific structure will unlock the door of psychology. The differences among the various sciences now are only those necessitated by the division of labor. Until psychology recognizes this and discards everything which cannot be stated in the universal terms of science, she does not deserve her place in the sun."

It is the purpose of those pages to give some brief account of the modern apparatus by means of which psychology has been enabled to assume more and more the character of an exact science, with definite and immutable laws governing individuals and groups, thus breaking down those barriers of isolation between mind and mind which language has but imperfectly bridged.

In his study of a given individual the psychologist applies certain tests whose results give him a very definite notion of the capacity of the individual before him, and of the class or group to which the individual belongs, when the said results are properly correlated in large numbers of instances. To begin with, what are known as anthropometric tests are applied. These include the diameter and girth of the skull, the weight, and the height, both standing and sitting. Secondly, come tests of physical and motor capacity, among which are the strength and endurance of grip, the strength of the back and legs, the speed of movement as shown by the act of tapping, the accuracy of movement as shown in taking aim and the steadiness of movement as shown in the act of tracing; this group also includes tests of the steadiness of motor control as shown by involuntary movements, and finally, what is known as vital capacity.

Of prime importance, of course, are the tests of sensory capacity, which include not only a delicate discrimination as to the sensitiveness and accuracy of the eye, the ear, the nose, the taste, and the touch, but also the sensitiveness with respect to pain and to pressure as well as a discrimination between dual impressions upon the skin. Lastly, there are various tests with respect to attention and perception, memory and other faculties of the intellect.

The fundamental principle underlying the conduct of all these tests is the same as in other sciences, namely, the *standardization of conditions*. If the conditions are varied they must be varied intentionally and for a definite purpose. Furthermore, no detail in the conditions governing the tests is trivial enough to be neglected.

First of all the laboratory itself must be carefully arranged according to certain specifications. It must include both dark rooms and rooms which are sound proof. It must be provided with electric power and it must be free from objects extraneous to the test in hand which might serve to distract the attention of the subject. The laboratory of psychology at Harvard, for example, comprises more than 20 separate apartments including five dark rooms, a sound-proof room, several rooms devoted to animal psychology together with the necessary vivarium, a library, a museum of apparatus, etc.

Since optical and auditory researches involve a knowledge of the laws of physics, there must be a physical laboratory forming a part of the installation. There must likewise be a chemical laboratory, since measurement of taste, odor, and chromatic sensations are made by means of certain chemical reagents. Among the general apparatus required are high power microscopes, delicate balances, thermometers, barometers, hygrometers, hydrometers, and various measures of length, surface and capacity. Other general apparatus are chromoscopes, cylinders, electric signals, devices for causing disks to revolve at various speeds, etc.

These instruments, all of which must be as perfect as possible, especially with respect to precision, have been combined in one way or another to form an enormous number of ingenius devices. These are so multifarious that they defy description in a single article. However, it is possible to describe certain types of the most important apparatus now in use in the laboratories of America, France, England and Germany.

These descriptions, with the accompanying illustrations, will it is hoped, give the reader some understanding of the value of modern psychological methods, and enable him to see why it is that the psychologist is increasingly called upon to lend his aid to the physiologist, the physician, the teacher, the jurist, and the industrial employer in every line of human endeavor.

Fig. 1. represents the olfactometer. Here the subject is holding a vial containing an odoriferous substance to one nostril, while the other is stopped with cotton. The vial contains a few drops of a fragrant essence or solution and the odor is received through a glass tube sliding inside a paper tube, closed with a stopper at its lower end and immersed in the receptacle; the test is made by seeing how far it is necessary to lift the glass tube, thus uncovering the paper tube through which the odor is diffused before passing into the glass tube in order to produce a sensation. By knowing the time required to lift the glass tube, the surface of paper uncovered (but with the disadvantage that the paper is not a definite body), and the co-efficient of the evaporation of the fragrant body in a single unit of time determined by the vapor balance it is possible to calculate the weight of the amount of evaporated substance which has passed into the apparatus and been received within the nostril. However, the vapor balance requires such delicate manipulation that some authorities criticise this method because of the difficulty of obtaining sufficient precision from the data furnished by the said balance.

FIG. 1. TESTING THE SENSE OF SMELL

FIG. 2. MEASURING THE SENSATION OF HEARING

In the method employed by Dr. Toulouse the keenness of the olfactory sensibility is measured in a perfectly calm and non-odorous atmosphere, at a temperature of 15°C. by means of 15 ccm. of an extremely weak solution of camphorated water contained in a glass tube having an internal diameter of 0.02 m. and an internal height of 0.06 m. with an emery stopper having an internal length of 0.01 m.; this tube is presented to the nostrils of the subject (the latter not being allowed to see it) for the space of three seconds and during an aspiration of average amplitude, in such a manner that the opening of the tube touches the nostrils and gives a *sensation* (i.e., an indefinite olfactory impression) or a *perception* (i.e., a recognition of the camphor). A control experiment is provided by presenting to the nostril of the subject a tube filled with distilled water.

A further step is the testing of the subject's capacity for perceiving and recognizing odors, by presenting to his nostril various solutions containing definite percentages of familiar fragrant substances, such as olive oil, orange flower water, violet water, rose water, garlic water, camphor, vinegar, etc. Aqueous mixtures are used instead of alcoholic solutions to avoid interference by the odor of the alcohol; in these cases the water acts mechanically by dividing the particles of the essences which would furnish too intense a stimulus in their pure state.

Finally, the non-olfactory sensibility of the pituitary mucous membrane can be measured by determining the weakest possible solution of ammonia at 27° C., or of ether, capable of occasioning a sensation or a perception.

The apparatus constructed by Toulouse and Vaschide to carry out these various tests is known as the osmi-esthesiometer and comprises a series of 54 vials of cylindrical form each having an internal height of 6 cm. and an internal diameter of 2 cm. and each having an emery stopper penetrating the vial for a distance of 1 cm. These vials are contained in two copper supports, placed in a wooden frame. One of these supports contains ten vials holding various odoriferous substances, while the other contains the series of vials holding solutions of camphor, of etherized water, and of ammoniacal water.

In Fig. 2 the audiometer of Professor Charles Henry is shown. This, as its name implies measures the delicacy and accuracy of the sense of hearing.

The auditory sense is tested for the impressions received with respect to the intensity of musical sounds or of noises, to the height of the note and to the timbre. The latter quality, however, results from a simultaneous complex of a great number of sounds of different heights; hence, its objective analysis is too difficult to permit the determination of exact measurement. Therefore the intensity and the height of the sound and its persistence are the characteristics chiefly studied.

A great variety of methods have been employed to determine the minimum sound perceptible. One method commonly utilized consists in a progressive increase of the distance between the subject and the source of sound, the latter having a definite degree of intensity taken as a constant. The source of sound may be a watch or clock, an electrically vibrated tuning fork, etc. The change of distance is made by a change of place, either on the part of the subject or on the part of the sonorous object; in this way the comparative distances at which different individuals cease to detect the sound can be determined. This change of place, however, is somewhat clumsy and tedious, and therefore, to avoid the necessity of it Professor Charles Henry has invented his audiometer in which there is interposed between the source of the sound and the ear of the subject an ebonite disk pierced with an orifice of known dimensions having a diaphragm of variable aperture; this instrument enables the investigator to compare the aperture and likewise the objective degrees of intensity upon the assumption that in each case the degree of intensity is proportional to the squares of the apertures of the disk and of the diaphragm.

A number of acoumeters have been constructed upon the principle of the telephone. In these the source of sound is a vibrating diaphragm and there is a rheostat which permits

the operator, by increasing the resistance of the circuit to diminish the degree of intensity transmitted to the receiver, which is held to the ear of the subject.

Another series of apparatus is based upon the principle of a variation in the intensity of the sound *produced* instead of upon a variation in the intensity *transmitted.* This is accomplished by allowing various bodies, such as hammers, metal spheres, cork balls, etc., to fall upon a constant metal surface, from varying heights.

This latter class includes the acousi-esthesiometer of Toulouse and Vaschide. In this apparatus the falling bodies consist of drops of distilled water, of a constant weight falling from a gradually increasing height upon a definite metallic object (an aluminum plate). Aluminum is chosen because it does not become oxidized, and the plate is inclined at an angle of 30 degrees to prevent the drops of water from accumulating and diminishing the sound of the vibration. A flask containing distilled water is attached so as to slide up and down to a standard, and the drops are allowed to fall with more or less rapidity by means of a stop-cock controling an orifice of variable size. All these apparatus, of course, must to be operated in an absolutely sound-proof room.

FIG. 3. MEASURING MUSCULAR SENSITIVENESS WITH THE MYO-ESTHESIOMETER

It is obvious that the precision obtainable by this instrument in denoting the degree of acuteness possessed by the ear would make it valuable in examining applicants for telephone operators as to their fitness for the post—a fitness at present only too often lacking.

In Fig. 3 there is shown the myo-esthesiometer devised by the well-known psychologists, Dr. Toulouse, Director of Experimental Psychology at the *Ecole des Hautes Etudes* of Paris and his late collaborator, Dr. N. Vaschide, for the purpose of measuring muscular sensitiveness. Here, the subject is blindfolded and is guessing weights by means of his muscular reaction.

The subject of muscular sensitiveness comes under the general head of the measurement of subcutaneous sensations. Not all of the networks of nerves possessing general sensibility are found near the surface of the skin; a large number of them start in the muscles, the tendons, the joints, the bones, and other parts of the organism capable of being the seat of sensation. The principle ones of these sensations having their origin in the deeper portions of the body include the vibratory sense, which is located chiefly in the bones, and the kinesic or kinesthetic sense, which is often called the muscular sense, and which is located mainly in the muscles, but also in the joints and even in the tendons.

To determine the absolute limit of sensibility to vibratory intensity, the instrument commonly employed is a sort of tuning fork, the one generally adopted being the acoumetric tuning fork of Pierre Bonnier. This tuning fork is set in vibration by suitable means and the rate of vibration is measured by a chronograph, or better still by photography. The forearm of the subject is extended with the closed fist resting upon its anterior surface upon a cushion. The experimenter sets the tuning fork in vibration, and at the same moment starts the hand of a pocket chronograph. He then places the tuning fork vertically by its handle in a state of equilibrium upon the top of the second knuckle and asks the subject to advise him of the instant when he ceases to perceive the vibration; at this instant he immediately moves the tuning fork into the same position upon the top of the third knuckle; the subject will again begin to perceive the vibrations and will again tell the experimenter when he ceases to perceive them. At this exact moment the experimenter will press the button of his stop watch and note the time elapsed. The necessity of changing the bone examined is due to the rapid fatigue to which vibratory sensibility is subject.

Kinesic Sensations.—The principal kinesic sensations to be studied consist of muscular effort exerted against a resistance as in the lifting of a weight; of static contraction, immobilizing a limb or any part of the body in a certain position, and dynamic contraction, *i. e.* a movement displacing a limb or any segment whatever of the body within certain definite limits.

Sensations of Muscular Effort.—The acuity of muscular sensibility can be measured by the smallest possible ratio between two copper buckets of similar volume and form, one of which employed as a standard maintains a constant weight, while the other has its weight progressively augmented by the addition of flat weights; these buckets after having been alternately suspended without any perceptible shock to a segment of the limb are differentiated. The myo-esthesiometer of Toulouse and Vaschide consists of a series of such buckets having the following weights:

First series	1 gr.
Second series	10 gr.
Third series	100 gr.
Fourth series	1000 gr.

The 1 gr. buckets are made of aluminum and the others of copper. Within the bucket of variable weight in each series there are placed flat weights of known weight permitting the value of the bucket with respect to the constant standard to be increased in the ratio of 1/1000, 1/100 and 1/10. In each series these flat weights are ten in number of a value ranging from one unit to ten units. In the first series the weight of the unit is 1 milligram, in the second series 1 centigram, in the third series 1 decigram, in the fourth series 1 gram, in the fifth series 1 decagram, in the sixth series 1 hectogram. In the first, second and third series the weights are made of aluminum, while in the fourth and fifth series they are made of copper. They are cylindrical in form and are surmounted by a hook.

The subject is seated in a comfortable and definite position by the side of a table in such a manner that his elbow alone is able to rest upon one edge of the table, while his arms are held in a horizontal position away from the table. The subject is blindfolded and told that he is desired to judge the weight of the little buckets by holding them in his hand and to tell the experimenter which seems to him the heaviest; in case he fails to receive a precise impression he is requested to say "I do not know."

The buckets are placed upon the joint of the index finger which is almost fully extended and the subject is then asked to judge the weight of the bucket by a movement of the forearm which is lifted from the elbow (the latter being supported as stated above) while the fist remains immobile and all the fingers of the hand except the index finger remain closed. Thus the muscular sensibility appertains almost solely to the biceps and to the anterior brachial muscle, on the one hand, and to the opposing triceps on the other hand. Triple presentations are made: the standard of a series is first presented, then another weight, and then the standard

again proceeding progressively from the weight which differs least from the standard, to the one which differs most. Between any two triple presentations there must be an interval of one minute in order to avoid fatigue, and after three or four triple presentations the subject must rest for several minutes, especially if the weights are heavy.

When the responses of the subject are found to be constantly exact, one obtains the value of a differential limit or "threshold" measured by a fraction, whose numerator consists of the weight in grams of the excess load added to the bucket having an adjustable weight, and whose denominator consists of the weight in grams of the bucket used as a standard.

In order to determine the absolute threshold of sensation one must produce anesthesia of the surface of the skin since otherwise the sensations of pressure, which precede the muscular sensations would render exact measurements impossible; this is accomplished by placing ethyl-chloride upon the index finger.

But it is possible to measure not only sensory sensibility and energy, but purely intellectual phenomena, such as memory, imagination, logic, the power of association and of abstraction, the capacity for discovery, etc.

Memory, of course, exists in animals, in a more or less rudimentary form and interesting comparisons can be made between this power as shown in animals and as exhibited in children and adults. All of the sensory perceptions can be remembered, and such memories may be very complex, particularly in the case of the five senses. Thus in auditory memory alone the mind can retain the impression not only of simple notes, but of chords, arpeggios, and tunes.

Visual memories have been classified under the heads of 1: Tables of complex, straight and curved lines; 2. Concrete objects; 3. Attitudes and expressions; 4. Complex scenes and physiognomies.

Finally, there are memories of words, phrases, and intellectual concepts.

Many tests of memory can be made of course, either with no apparatus or with nothing more elaborate than a piece of paper and a pencil, or a blackboard over which a shutter can be swiftly drawn.

Fig. 4 shows Lahy's electro-magnetic apparatus for this purpose.

Sensations of heat and cold can be measured in various manners. A clever device for this purpose is the thermo-esthesiometer of Toulouse and Piéron. This consists of a double metal funnel having an electric resistance between its two walls. The end of the funnel is provided with a stop-cock regulating the flow of drops of distilled water through a calibrated orifice. A thermometer is immersed in the funnel, the end of the reservoir being above the level of the orifice; a spiral agitator surrounding the thermometer maintains a homogeneous temperature of the mass of water. A cardboard screen is placed at the base of the funnel with an orifice for the passage of the drops. An important feature in the use of this device is to allow the drop of water to remain on the skin very briefly, since evaporation at once produces a cooling sensation.

SENSATIONS OF PAIN.

Cutaneous sensations of pain have the peculiarity of being excited by a wide range of stimuli including pressure, pinching, piercing, heat and cold, and electric discharges. This is why pain was long held to be a concomitant of any violent exertation, instead of a definite sensation, as it has now been demonstrated to be. It is measured by various instruments, one of which is the algoesthesiometer of Toulouse and Piéron.

Fig. 5 shows the method of testing susceptibility to heat and cold. Here the subject is measuring calorific sensations with his hands crossed.

STATIC SENSATIONS.

There are certain sensations which enable us under normal conditions to recognize the position of the limbs and of various segments of the body with respect to each other, even when we have forgotten the movements to which these attitudes are due. Thus when we first wake in the morning we know whether we are lying on the back or on one side and whether the limbs are drawn up or extended.

An instrument designed to permit the study of static sensation in the arm is the schesi-esthesiometer of Toulouse and Piéron. This consists of a grooved standard and a circular support which can be inclined so as to swing backward and forward. The surface of the support can be placed by means of the grooves at any distance above the ground from 0.90 m. to 1.90 m. The foot of the standard can be moved upon the surface of a circular piece of linoleum upon which there is drawn a central circle and a series of radii separated by distances of 10 degrees.

FIG. 4. ELECTRO-MAGNETIC APPARATUS FOR TESTING MEMORY

The arm is placed in a given position with the hand resting upon the support which is so inclined as to be in a straight line with the axis of the extended arm; this position can then be defined as regards its height and its angular distance with respect to a plane which is perpendicular to the interocular line. The subject is required to compare this position with other positions.

DYNAMIC SENSATIONS.

Dynamic sensations are those which give us information as to the extent of movements of the limbs or of segments of the body. The instrument described above can be employed to study the differential sensibility of passive movements of the wrist joint. The hand being placed in the usual position upon the support and brought to the height of the horizontal plane of the extended arm; the support is then inclined at a constant rate of speed and at a definite angle, *e. g.* at an angle of 30 degrees per five seconds; then after having again placed the hand in the horizontal position, the movement is recommenced at the end of five seconds with the same rate of speed and a displacement of somewhat greater or somewhat less extent is made. The subject is required to inform the experi-

menter as soon as he can perceive a difference in the extent of the displacements, and which appears to him to be the greater. The difference between the two displacements is gradually increased until exact responses are obtained determining the threshold of sensation (*i. e.* a detected difference) and the threshold of perception (*i. e.* the determination of the extent of the difference). The habitual test consists in effecting the same displacement twice in succession.

Active Movements.—Active movements are studied by causing the subject of experiment to displace a movable body along a definite distance. There are various apparatus employed for this purpose; sometimes grooved boards are used, a pencil being employed to follow the contour of the groove. This method enables the experimenter to determine the threshold of differentiation of forms—for example, by causing the subject to follow the contour of circles which have been more or less flattened so as to assume an elliptical form it can be determined what is the slightest degree of flattening capable of being perceived.

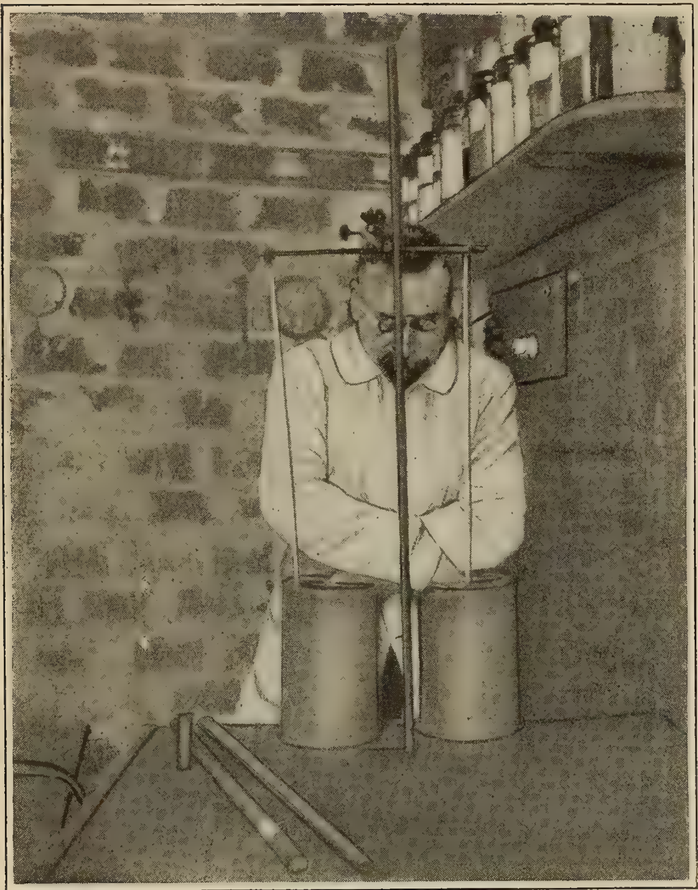


FIG. 5. MEASURING CALORIFIC SENSATIONS WITH CROSSED HANDS

Various other apparatus have been devised to measure the extent and precision of various dynamic motions.

MEASURING THE SENSE OF TASTE.

The sense of taste is so closely connected with that of smell that it is often difficult to differentiate the two, and there are in fact a large number of pseudo tastes or savors which result from the collaboration of these two senses. Fortunately, however, certain stimuli exist which have a distinctive effect upon these organs, thus enabling them to be isolated for the purpose of study.

Some experimenters make use of powders to stimulate the sense of taste while others employ solutions, which are placed upon the tongue by means of the finger, a brush, a sponge, or a tube; others still make use of electric currents.

Certain definite methods have been formulated by Dr. Toulouse for the study of taste. He makes use of salt, for salty savors, of saccharose to produce sweet savors, and of quinine for bitter flavors and of citric acid for acid flavors. These substances are not only well defined and familiar to all normal subjects but are readily soluble in distilled water.

These solutions are prepared in decimal series. Each is placed in a flask through whose rubber stopper a dropper is inserted. The dropper is carefully made so as to produce standardized drops having a constant volume of one-fiftieth of a cubic centimeter whatever the concentration and having approximately the same weight. Sixty of these flasks are placed in a frame made of copper which can be placed in a water bath so as to maintain a constant temperature of 38 degrees centigrade. This apparatus is called a gueusi-esthesiometer. The flasks must be protected from evaporation since this will alter the degree of concentration. Furthermore, they should frequently be refilled. The drops are allowed to fall upon the tongue from a height of one centimeter. At this distance there is practically no sensation produced by contact—thus the only sensation experienced is that of taste. The subject of the experiment is seated comfortably with his head held by a support and is then told to extend his tongue as far as possible. The surface of the tongue must be perfectly dry before the application of each drop so as to prevent diffusion, which would interfere with the accuracy of the experiment, especially in cases where certain definite areas of the tongue are being tested with regard to specific sensibility. The tongue must be held perfectly steady, if necessary by holding it in the hand, the latter being covered with a handkerchief. The subject must obey the orders of the experimenter promptly, either holding the tongue extended or withdrawing it and pressing it against the palate in the endeavor to bring out the taste of the applied drop. There is an interval of one minute before the fresh drop is applied. In the case of bitter substances this interval is necessarily much longer, extending even to five minutes, since bitter tastes have a tendency to persist. After each application the mouth must be rinsed with 5 ccm. of distilled water having a temperature of 38° C.

THE MEASUREMENT OF VISUAL SENSATIONS.

The sensations derived from the eye are extremely complex and their investigation is, therefore, a matter of much delicacy. The eye is measured first with reference to its capacity for luminous sensation, tests being made for the perceptible minimum of sensation and for the differential minimum. Secondly, it is measured with respect to its capacity for chromatic sensation, *i. e.*, its sensitiveness to color. The first tests have reference to sensibility as a whole to chromatic intensity. Next the extreme limits of chromatic sensibility are determined. Thirdly, the power of differentiation between chromatic tones is made, and lastly, the sensibility to shades and to chromatic saturations is determined.

Other tests include those for keenness of vision, for the extent of the visual field, and for the persistence of luminous impressions. In these various branches of visual measurement a large variety of apparatus is used for which the best optical glass, including lenses, prisms, ground glass plates, etc., must be employed. Furthermore, there must be all sorts of spectacles to correct abnormal vision. The importance of this will be recognized when it is remembered that a large percentage of individuals have eyes which are unlike each other, in one respect or another, besides the difference between individuals. Furthermore, even in a perfectly normal eye the focusing power gradually and continually changes with increasing age. One of the commonest instruments used to determine luminous sensibility, is the photoptometer of Charpentier, an arrangement of two plano-convex lenses in a tube having between them a diaphragm provided with a device sometimes known as a "cat's eye," *i. e.*, an aperture which can be made wide or narrow at will by means of an adjustable shutter. A ground glass plate covers the end of the tube.

The subject of experiment must remain for a quarter of an hour beforehand in a dark room, so that his eye is adjusted to entire obscurity. The photoptometer is placed upon

a table and the electric bulb forming the source of light is placed in a dark box connected with the tube of the apparatus, in such a manner that not a single luminous ray, except those which enter the tube can pass into the room. The subject has the eye piece to which he must apply his eye indicated to him by the sense of touch. When he first applies his eye the

FIG. 6. DETERMINING THE DEGREE OF DILATATION OF THE EYE

adjustable aperture is completely closed; he then removes his eye and the aperture in the diaphragm is gradually opened, the subject applying his eye every twenty seconds, for a period of two seconds each time. He is required to announce the exact instant when he believes himself able to observe even the faintest degree of luminosity upon the screen.

The differential minimum is obtained by the differential photoptometer. This is made by adding to the tube of the simple photoptometer a rectangular box, upon which is mounted at a right angle a tube identical with the first. Two luminous sources of equal intensity are placed opposite each tube at the convergent focus of the lenses opposite the plate of ground glass; the adjustable apertures are open to the same extent. But the light which comes from the second tube encounters in the rectangular box a plane sheet of glass, placed in a diagonal position, which, reflecting the rays at a right angle, projects them upon the anterior surface of the screen, while the posterior surface of the screen receives the light from the other source. The eye observes the screen illuminated by both sources, one of these illuminations being by direct transmission, while the other is by diffused reflection. But to effect a comparison of the two sources it is necessary that each half of the screen should be illuminated by one of the sources alone. Accordingly, a sheet of opaque black paper is placed behind the screen covering one-half of it. This half will, therefore, receive only the reflected light, while to prevent the other half from receiving reflected light the corresponding half of the diffusible surface terminating the lateral tube is covered with opaque black paper. The subject is now required to compare the two sources of light in this manner and by modifying the aperture of the lateral diaphragm the intensity of the reflected light can be increased or diminished until a differential perception is obtained.

Another interesting instrument which is shown in Fig. 6 is the pupilometer. This is employed to determine the degree of dilatation of the pupil of the eye or the distance between the two pupils.

MOTOR OBJECTIVATION.

The somewhat technical title of "motor objectivation" includes the investigation of certain phenomena which are of vital importance in the industrial world, since by means of the tests here applied to inviduals workmen can be differentiated with respect to their specific aptitudes as well as their general capacity.

To begin with, voluntary reaction is measured, the reaction times being carefully noted. These reactions are caused by various apparatus designed to produce stimulation by means of pressure, by electricity, by heat, by sound, by light, by smell, by taste, and by pain. The reaction times are recorded by specially constructed chronoscopes.

Motor rapidity is next measured, both as regards simple movements and with respect to complex movements. Precision of movement, whether simple or complex is also carefully measured, as well as what is called motor symmetry.

An interesting division of this subject is concerned with motor suggestibility and involuntary motions. The ultimate limits of motor reactions are likewise carefully studied, together with motor inhibition.

But perhaps the most interesting branch of this subject to the average reader deals with motor fatigue and variability of effort.

THE MEASUREMENT OF MOTOR FATIGUE AND VARIABLE EFFORT.

Motor fatigue can be determined by the diminution in the intensity of movements made in a definite period of time. This diminution can be investigated as a phenomenon of fatigue pure and simple by means of an electric stimulation of the muscles. But in the ordinary affairs of life the question of fatigue is complicated by the fact that as the degree of fatigue increases it is combatted by a progressive increase in the intensity of the nerve force directed to the muscles; this, of course, naturally tends in its turn to produce a nerve fatigue which eventually causes a cessation of effort. On the other hand, it has been demonstrated by Mosso that voluntary effort tends to increase in direct proportion with muscular fatigue,

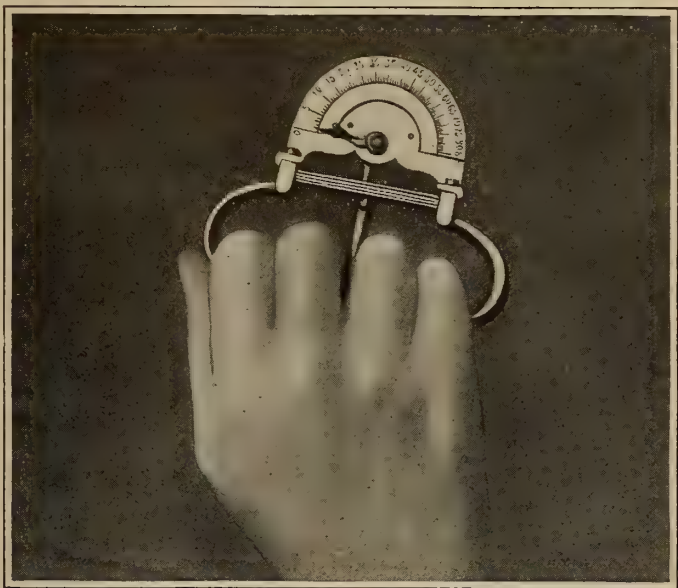


FIG. 7. REGNIER'S MUSCULAR DYNAMOMETER

a fact which most people have noted in their own experience. The investigator, therefore, in studying fatigue produced by voluntary labor seeks to determine this growing intensity of effort.

Individuals can even be classified with respect to the intensity of the voluntary effort, which they put forth in the attempt to counteract the decrease in the amount of work done due to fatigue. Such a classification carefully made would

be invaluable to an employer of labor, as wêll as to pedagogues. This coefficient can also be used to make a comparison beween an individual working under his own guidance, *i. e.*, a man who is being "left alone" and the same individual when subjected to the influence of various stimuli, such as admonitions, curses, prayers, the hope of reward, the fear of punishment, or the artistic delight in achievement. Perhaps this explains the well known popular assumption that only an expert in profanity makes a good mule driver.

A decrease in energy can be made by successive compressions of a dynamometer, by Mosso's ergograph, or with the dynamograph invented by Professor Charles Henry of the Sorbonne. Fatigue can also be tested by a decrease of rapidity in certain simple movements, as for example, in the so-called tapping test. This see-sawing produced by steadily increasing fatigue and by spurts of energy designed to make up for the loss causes the descending curve which indicates a fatigue to be very irregular in character, showing individual variation.

The dynamometer consists of a metal spring which is compressed by the hand. Its defect consists in its hardness and stiffness which produce pain, which tends to inhibit the effort. Mosso's ergograph is far better. In this a weight is lifted by the repeated contraction of the middle finger, which wears a ring attached to a string which runs over a pulley, the weight being at the other end of the string. The weight used must be neither too large nor too small, 3 to 4 kg. being best. The proper rhythm is one contraction of the finger every 2 seconds; a slower rate permits the finger to rest, so that according to Maggiora's ergogram a rhythm of 10 seconds prevents fatigue. Too fast a rhythm, on the other hand, tends to produce cramp. The defect of the ergograph consists in the impossibility of maintaining a sufficient degree of immobility in the arm to prevent coöperation by fresh muscles of arm and shoulder.

Professor Henry's dynamograph represents a distinct improvement. Here the work is done by compressing a rubber bulb filled with mercury communicating with a manometer. Since the mercury is not rigid the effort causes no pain. The surface of the mercury bears a float connected with a registering device. The bulb must be squeezed rather slowly to prevent the mercury from rising above the float.

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A NEW THEORY CONCERNING THE NATURE OF THE PHENOMENA OF LIFE.

By Felix Regnault.

Our knowledge has now reached such a degree of advancement that we are enabled to regard the phenomena of life from a new viewpoint. This consists in regarding the living being as consisting of two substances, one of which is actually living while the other is organic in nature.

The living substance may be termed the "energide"; in this class are included the nucleus, the protoplasm, and certain intracellular elements. The energides manufacture organic products. Some of them remain intracellular, while others are pericellular and still others are extracellular. Among these latter are those which are architectural in character.

It is not true as stated in the classic definition that a tissue is formed simply by the union of cells having a similar constitution; it comprises also an organic product. Tissues are divided into three classes according to the quantities which they contain of this product, as follows:

1. The tissues having numerous and contiguous cells with a not very abundant intermediate organic product. Examples of such tissues are the epithelium and the endothelium. In these tissues the cell has an important functional rôle while the organic products has a secondary rôle.

2. The tissues composed of rare and isolated cells immersed in an abundant organic product. Certain lower organisms, such as the volvox are composed of cells of the same kind united by an abundant gelatinous substance. Among the higher creatures the conjuctive cartilaginous and osseous tissuer are formed in this manner. The cells of these tissues are specialized in the production of the aforesaid organic products and have no other rôle. The organic product has an important functional rôle. The grafts of these products succeed well upon condition that the cells which they enclose are killed. These dead cells are then replaced by the cells of that part of the body which acts as the host for the grafted piece and these cells readily invade the organic product.

3. Tissues constituted exclusively by the organic product. The latter proceeds from a pericellular or an intracellular secretion which is liberated by the death of the energides. Examples of such tissues are the vascular canals of wood among plants and the epidermis among animals. Finally, such a tissue is sometimes produced by an extracellular secretion, such as the shell of mollusks.

In every tissue an effort must be made to distinguish between that portion which is the truly living substance and that portion which is merely the organic product. There are cases in which this distinction is very difficult to make.

The corpuscles of the blood are living to begin with, while they exhibit a nucleus, and are erythroblasts. They continue to remain living in the batrachians among whom they retain their nucleus. But in the higher mammals they lose the nucleus and are formed solely of hemoglobin and then become merely an organic product.

The muscular substance is derived from protoplasm; from the point of view of embryologists it is to be regarded as an organic product. Protoplasm has long been regarded as the vital principle par excellence. But today it has diminished in importance, while the nucleus has increased in significance. However, the habit has continued of considering protoplasm to be a living substance as well as a nucleus. However, the properties, movement and excitability of protoplasm can be explained by physico-chemical laws. When separated from the nucleus it perishes; by itself it is incapable either of assimilation or of reproduction. Contrary to the nucleus it possesses an incomplete vital energy; to all appearance it is capable of acquiring the vital energy of the nucleus but incapable of producing that energy.

The laws which govern the phenomena of life are a subject of debate. Some authorities accept the animist theory, others that of the unicists, and still others, finally, that of the vitalists. In these discussions we ought to make a distinction between the organic products, which necessarily obey physico-chemical laws and the energies. It is quite possible that the latter produce a special form of energy which differs from other forms of physical energy as much as electricity differs from heat or from light.

Conclusion.—Living organisms may be regarded as composed of two substances, the living substance or energies and the organic product. These two substances form tissues in which they exist in variable quantities; the tissues may be classified by taking as a basis the quantity of organic products which they contain.

Certain substances which are commonly regarded as being living are in reality organic products: such are the corpuscles of the blood and the sarcolemma of the muscles. It is possible that protoplasm itself is merely an organic product of the nucleus—in any case it possesses an incomplete vital energy which it acquires from the nucleus.

While the organic products are governed by physico-chemical laws, it is easy to believe that the energides produce a special form of energy which is peculiar to life.—Presented by Dr. Ch. Richet before the French Society of Biology in Paris at the Session held December 6, 1919.

The Evolution of Efficiency in the Animal Kingdom*

The Principle of the "Shortest Line" in Action

By J. S. Szymanski, Vienna

IT is my purpose in this article to direct the reader's attention to the element of regularity found in the various activities of men and animals when regarded from the point of view of efficiency.

When we observe the various kinds of action made by men and animals, we are impressed with the fact that in most cases[1] animals as well as men act as if they meant to attain the object of their action as directly as possible, i.e., by the shortest path[2]. This principle is not immediately evident when we regard the activity of a single individual alone. The regularity above mentioned impresses us only through a comparison of a given action in different individuals or in different kinds of animals.

In order to obtain a clear perception of such regularity of actions it is advisable to make special observations under five heads, which may be stated as follows:

1. The observation of similar instinctive action in divergently constructed kinds of animals belonging to the same class of animals.
2. The observation of similar instinctive action in individuals of the same kind under different conditions of the organism.
3. The observation of similar instinctive action in the same individual and the effect of different degrees of intensity exerted by the same sort of stimulus.
4. The observation of different degrees of development of a newly acquired habit in the same individual during the course of the process of learning.
5. The observation of the execution of the same rational action by an individual at different ages.

Upon examining more closely each of these cases with respect to the question here involved, the first thing to be noticed is that in the same class of animals those kinds which are anatomically divergent perform the same instinctive action in such a manner as to make use of the principle of the "shortest path." To mention merely one example, insects cleanse their antennæ "in the mechanically simplest manner." This opinion is founded upon the following observations: as a general thing long feelers in those kinds of insects which possess masticating mouth organs, are cleansed by means of the latter; while short feelers are cleansed with the fore legs. In those kinds which do not have masticating mouth organs, both the long feelers and short feelers are cleansed by the fore legs. When, however, the masticating mouth organs are small and feebly constructed or when the feelers are comparatively stiff and inflexible even those kinds of insects which possess masticating mouth organs, cleanse their comparatively long antennæ with the legs. But even comparatively short antannæ can be cleansed with the mouth organs when the feelers have protuberances at their ends, or when the legs are comparatively short. These examples serve to show that the same action in different kinds of animals is always performed by those organs which enable the creature to perform the operation in the most direct manner, i. e., by the shortest path.

If we turn now to the observation of the same action in individuals of the same kind in different conditions of the organism, we perceive, to begin with, that when we remove some agent which is normally employed for the performance of an action, the organism is able in many cases to perform the said action with some other organ substituted as an effective agent. Thus, for example, a frog which has had some acid sprinkled on one side of the body usually wipes itself with the hind leg on the same side. But if this leg be cut off it still wipes away the acid with the hind leg on the other side (Pflueger). Or, to take another example, the red ant cleanses its feeler with the foreleg upon the same side. But if the right foreleg be amputated and the ant wishes to cleanse the left feeler, it turns its head towards the left side and seizes the left feeler with the cleansing spur of the right foreleg with which it then combs its feeler. It is quite obvious that this vicarious movement

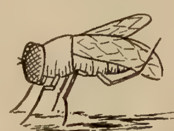

FIG. 1. THE WING-WIPING REFLEX IN A FLY (*ERISTALIS TENANS*)

cannot be executed like normal ones along the shortest path. However, it is not necessary to remove one of the effective agents in order to exert a mechanical influence upon the performance of the action. It is quite sufficient to produce an enfeebling of the entire organism or else of the sensory activity in order to hinder the execution of the action along the shortest path. Thus it can be shown, for example, that when in an animal which is capable of making "experimental movements," we produce a heightened general mobility, through the influence of external or internal factors, it is able to move with a comparatively greater average speed in a more or less direct line either to or from the source of stimulus, arresting its progress at only a few points in order to execute "experimental movements." While, on the contrary, there has been produced in the same animal a diminished general mobility through the influence of external or internal factors, it will move with a comparatively decreased average speed either to or from the source of stimulus along more

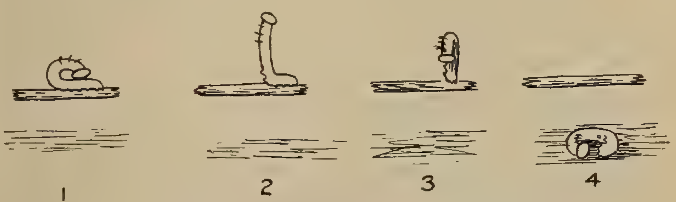

FIG. 2. THE TRANSFORMATION OF THE STRIKING REFLEX INTO THE ROLLING-UP REFLEX

1. Striking reflex of type B (= local defense reflex).
2. During a prolonged irritation the body erects itself more and more, the legs let loose of the underlying support, the fore part of the body bends itself laterally, (3) and the caterpillar falls off the support. During its fall the caterpillar revolves itself along its longitudinal axis at an angle of 90° in such a manner that the abdominal side is made to lie inward.

or less direct paths, and will arrest its progress at many points in order to execute experimental movements.

The observations of the same action executed on the one hand by normal individuals and on the other hand by enfeebled individuals of the same kind. shows that the organism operates along a shorter path when in a normal condition than when in an abnormal condition.

The impression that the organism operates along the shortest path is further strengthened by the observation of the same instinctive action in the same individual and the effect of

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[1]The exceptions would be, for example, the "courtship" of animals, the crossed reflexes (Luschinger), and the cleansing of the antennae by cockroaches.

[2]In the most economic manner, therefore,

different degrees of intensity of the same stimulus. When, for example, one strokes the wing of a fly (*Eristalis tenax*) once or several times with a thread, the little creature raises the hind leg on the same side and wipes its wing with it, as if it were trying to wipe something off of the wing[3] (Fig. 1). When, however, we continue the stroking of the wing (the consummation of the overflowing excessive stimulus!) or increase its intensity, the insect flies away.

This action makes it quite evident that the whole organism does not change its position in order to escape the effect of the stimulus until the local protective reflex fails to accomplish its purpose. Still another example of the same phenomenon may be observed in the caterpillars of many butterflies (some kinds of the *Vanessa*, and *Pieris brassicae*). When we lightly touch the back of a resting caterpillar of one of these kinds with a small stick, the little creature will curve the forward part of is body backward endeavoring to reach the source of the irritation with its mouth from which there issues a drop of blood ("striking reflex of type B"). If the irritation of the back be continued the caterpillar either moves away or else the striking reflex passes over into an incomplete rolling-up reflex and the caterpillar falls down off its support. This is the case also in which the local defence reflex passes over into a general flight reflex. It indicates that the organism first attempts to get rid of an injurius factor by the shortest path and does not attempt other action until the first fails to be successful.

This regularity of action is especially evident in the process of learning. The observation of the different degrees of development in a newly acquired habit in the same individual during the course of the process of learning shows that the animal or the human being constantly selects the shortest path during the progress towards perfection in the execution of the action concerned until finally, when the process of learning has been perfected, the action is executed along the shortest path. Herein lies the principle of learning through the elimination of unnecessary movements or in the well-known phrases of an American authority: "The dropping of useless movements."

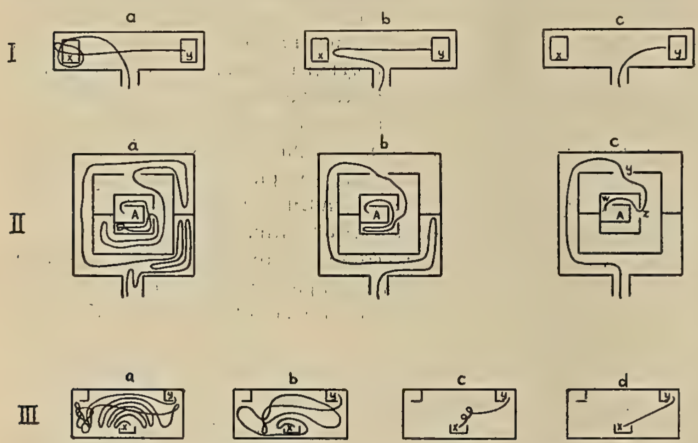


FIG. 3. BEHAVIOR OF ANIMALS IN A LABYRINTH

I. Behavior of a gold-fish in a labyrinth at the beginning of a series of experiments (*a*), during its further progress (*b*), and at the conclusion (*c*). *X* = a closed exit, *y* = an open exit.

II. Behavior of a rat in a labyrinth at the beginning of a series of tests (*a*), during its further progress (*b*), and at the conclusion (*c*). The dwelling cage and food are located at A; y z w represents the shortest path from the front of the enclosure to A.

III. Behavior of a dog in a testing space at the beginning of the series of tests (*a*), during its further progress (*b*, *c*) and at the conclusion (*d*). The front of the enclosure is at *x* and the food is at *y*. In all the figures the heavy lines represent the path taken by the animal.

[3]Among all the kinds of flies which I tested in this manner only the *Eristalis* exhibited this reflex. It is easiest to slip up on this fly without startling it when its reflexes of forward motion have been made sluggish through some local condition, such as the weather (a rainy day) or the coming of twilight (the beginning of the period of nocturnal rest).

As an example of this I will mention merely the process of learning to peck in chicks (Morgan, Breed) and the behavior of animals during the process of becoming accustomed to find their way out of a labyrinth (Fig. 3). Learning through the elimination of superfluous movements is especially fitted to show clearly that when the process of learning has been completed the given action is accomplished along the shortest path. Finally, when we regard the accomplishment of the same rational act in a single individual at different ages, it becomes evident that in the earlier years of life such actions are not accomplished in a perfectly rational manner, i.e., they are not performed by the shortest path. It is only with advancing age that the individual performs acts in a thoroughly rational manner, i.e., along the shortest path. By way of an example I would call the reader's attention to the results of the so called "sweeping the labyrinth test." This test consists in the removal of bits of gravel from a labyrinth in the form of a snail shell (Fig. 4-I).

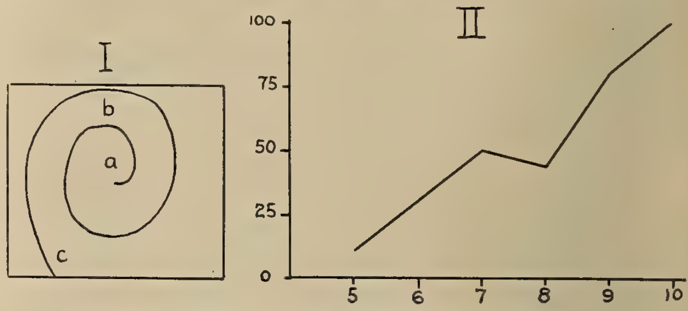


FIG. 4. TEST OF CHILDREN IN A LABYRINTH

I. The labyrinth in the shape of a snail shell.

II. The curves are intended to make evident the capacity for rational action as shown by the labyrinth sweeping test. The cases in which the child acts rationally, *i. e.* in which it begins to sweep at *a* are shown upon the ordinate (in percentages), while the age in years is placed upon the abscissae.

It was found that children did not perform this act rationally, i.e., did not begin the sweeping at *a* until they had reached the age of about nine; children from five to eight years of age, inclusive, did not act rationally, since they began to sweep at *c* or *b*. The rational action only is a perfected action since it is performed along the shortest path. As this example shows, the development of rational conduct progresses with advancing age in the direction of the performance of a given act by the shortest method.

The perfecting of behavior in adults and also in successive generations of mankind follows the same direction. For thorough scientific researches, *i. e.*, through the process of learning, successive generations eliminate the irrational manner of conduct of their ancestors (consider, for example, the psycho-technical principle of the scientific management of business). In this case a similar process takes place, so to speak, to that which we have observed in the progress of learning through dropping useless movements. Consequently the aforesaid regularity is to be discovered by the observer in all types of action!

OZONIZING POWER OF SOLAR RADIATION AT HIGH ALTITUDES.

As a result of experiments at Mont Blanc Observatory to determine the part played by the solar radiation in the production of atmospheric ozone at a high altitude, it is shown that at an altitude of 4,360 meters the solar radiation has no ozonizing power, and that the ozone found in the middle and lower atmospheric layers is not formed there by the direct and local action of the sun. The therapeutic effects of the sunbath cure cannot, therefore, be attributed, as has been hitherto imagined, to a chemical process of this nature.—*Comptes Rendus*, Nov. 24, 1919. Abstracted by *The Technical Review.*

Human Grafting

The Brilliant and Successful Experiments of Dr. Serge Voronoff

By May Tevis

OUT of the monstrous evil of the war is it comforting to reflect that at least some good has come in an enormous stimulous given to medical science and surgical skill. Nowhere is this more marked than in the marvels of human grafting, which have performed actual miracles for countless wounded, crippled and disfigured men.

A well-known European surgeon, Dr. S. Voronoff, formerly a pupil under the famous Dr. Alexis Carrel of the Rockefeller Institute, and himself the author of the valuable work, a "Treatise Upon Human Grafting," contributes to a late number of *La Revue* (Paris), an article upon this vitally important subject. He says: "It is evidently not sufficient that the human grafting should exhibit good results for a limited time only; it is necessary that the result should be durable, and that the transplanted organ should give rise to no trouble in the new organism. On my return from New York in 1910, where I followed the work of Dr. Carrel, I undertook certain experiments in order to determine the conditions which might insure the definite vitality of grafted organs. I soon perceived that the organs borrowed by one animal from another of the same species sometimes exhibit signs of retrogression and atrophy. I concluded that the borrowed organ failed to find the proper vital conditions and nutritive environment in its new host necessary for its continued existence. Every living being represents a highly personal individual entity, possessing a peculiar temperament and blood character, which, while similar to that of other individuals of the same species, nevertheless has certain peculiarities which defferentiate the intimate biological conditions of the cell life in our organs. This indivdual difference varies in degree, and it occured to me that it must certainly be possible to find some individuals which were more closely similar than others among the same species. I based this opinion upon the fact that some individuals are found whose blood when mingled forms a uniform liquid wherein it is impossible to distinguish the portions coming from one or the other. There are others on the contrary whose blood immediately coagulates in contact with the added blood, and there are still others whose blood acts like an acid upon the blood which is poured into it, dissolving and destroying the red corpuscles. An organ borrowed from an individual whose blood is very different from that of the individual in which it is planted is naturally certain to die, since its nutritive environment is suddenly changed. On the other hand when the transplanted organ finds the same conditions which governed its previous life it continues to live in a normal manner. The success of the grafting depends therefore upon the affinity of the two creatures, upon the type so to speak to which they both belong. These ideas naturally led me to the conclusion that this affinity would be found especially among the members of the same family. In place therefore of selecting animals at chance, I undertook a series of experiments between related animals; these experiments were made at the Clinique Sainte-Marguerite, where I was assisted by Prof. Hobbs, Dr. Montalti and Dr. Rosanoff, and the Veterinary Surgeon, Buqueux. My first subjects were sheep, selected because shepherds are commonly very familiar with the relationship of the animals and their flocks. I had the immense satisfaction of finding my hypothesis confirmed by these experiments, and in 1912 I was able to present before the Congress of Surgery, held in Paris in 1912, transplanted organs exhibiting perfect vitality at the end of two years. In 1913 I was able to give a convincing demonstration of the truth of my theory by exhibiting at the International Congress of Medicine a lamb which has been conceived by a ewe, whose reproductive organs had been transplanted from her sister sheep after her own had been removed.

"Since the conditions of successive grafting even of complex organs has thus been demonstrated, the biological affinity should always be sought for, either in members of the same family, or in individuals not related, but in whom biologic affinity has been detected by the examination of the blood. It is obvious that success is still more certain when it is possible to take the graft from the individual itself since the transplanted organ then continues its existence without the change of previous conditions of life."

Having thus proved his theory by animal experimentation Dr. Voronoff proceeded to undertake human grafting. Shortly before the outbreak of the war he reported to the Academy of Medicine in Paris a remarkable case wherein he improved the condition of a child who was idiotic because of the atrophy of the thyroid gland by grafting upon it a thyroid gland of a monkey, and a still more remarkable case where he grafted a portion of a thyroid gland of a mother upon her son with remarkable results. The latter, a youth of twenty, resembled a child of ten in appearance, having been born without a thyroid gland. He had remained small, fat, with a neck sunken in his shoulders and the cretinoid face which recalls an animal. This boy, dull and apathetic, able to pronounce only a few intelligible words, and hiding in corners like a frightened animal, presented a painful contrast to his brother only a year older, but a big vigorous fellow fighting bravely at the front. In 1915 the mother, a strong and intelligent woman, gladly consented to have a portion of her own thyroid gland removed and grafted upon her son. The operation was highly successful, and at the end of a year an absolutely marvelous change was found in the afflicted youth. He had begun to grow, gaining sixteen centimeters (over 6 inches) in the year, his head was no longer sunken between his shoulders. The bloated look had disappeared; best of all his mind had been awakened. He was able to talk distinctly and he is at present earning his living by working in a bakery.

Dr. Voronoff says further: "These facts, together with many others of a less general character, such as the transplantation of foetal membranes, which I employed to restore the skin, and the facts published by Delbet, Tuffier, Walther, Vuttner, Lexer, etc., contributed to create favorable opinion toward the project of enabling our wounded men to profit by this new acquisition of science. In December, 1914, four months after the beginning of the war, the 'Service de Santé,' created at the Russian Hospital in Bordeaux, of which I was then in charge, a section of osseus grafting. The hospitals of the eighteenth Région were invited to send to this section all their wounded men suffering from lesions accompanied by loss of bone. Later in June, 1915, when the 'Service de Santé,' with the assistance of the generous philanthropist, N. de Spoturno-Coty, had created a hospital especially devoted to grafting, Auxiliary Hospital No. 197, and Paris hospitals were likewise invited to send there such wounded men as might be assisted by grafting. I therefore received a large number of men having wounds of this description, wounded men whom my colleagues had been wise enough not to subject to amputation even in cases where arms and legs were hanging like rags. In this new surgery there was still much investigation to be done as to the best instruments, process, operative conditions, etc. In times of peace the surgery of grafting was of too recent a date and its field was too narrow to have been fully systematized. The only subjects which had been conceived by a ewe, whose reproductive organs

those sufferings from tumors of the bones, and even in these cases the employment of grafting was very exceptional since the minds of surgeons were still imbued with the ancient ideas which inclined them to practice amputation whenever the continuity of the bone was interfered with for a considerable length. The first problem is to decide where to take the graft; as I have said, it is necessary that these grafts should find the same nutritive environment, and the same biological conditions in the new host, which they previously had. When the wounded man is able to bear it, the best thing therefore is to take the needed fragment of bone from his own body. At first the idea seems paradoxical, since the

FIG. 1. FRACTURE OF THE UPPER THIRD OF THE LEFT TIBIA (SHIN BONE) WITH A LOSS OF 4½ INCHES OF BONE

Entered hospital 40 days after receiving wound, his leg being immobilized in a plaster cast.

proposition is to repair a fractured leg or arm by breaking another bone of the wounded man. Happily the reality is less tragic than it seems. Nature has thoughtfully given us a bone which we can dispense with, without suffering any inconvenience. This is the fibula, that thin but solid bone which is able to bear a weight of 70 kilos (154 pounds) without breaking, and which is fastened to the tibia. Our body is supported by the femur which is joined directly to the tibia and not to the fibula, which we retain as a vestige of an ancestral condition, and which we can dispense with without trouble, at any rate without its upper part. Moreover, there are many animals which are excellent runners and yet do not possess this bone. When taken from the invalid himself this bone naturally finds the same vital conditions to which it is accustomed, and it is grafted with great ease in the new area to which it is tranplanted. Placed between parts of bones which are larger than itself, such as the femur or the tibia, it not only welds the broken parts together but it becomes larger itself, becoming indeed almost as large as the femur or tibia, thanks to the more abundant nutrition which it receives from the bigger blood vessels in its new position, and thanks also to the marvelous adaptability of every organ to its new function. This growth in volume naturally requires a certain length of time, sometimes a year or longer. But this bone is not the only one which can be used as material for grafting. The graft is often borrowed from the tibia, by cutting a piece of a certain thickness out of it, especially to repair an arm bone. The tibia is such a thick bone that it can stand such a loss without injuring its solidity; in fact, the wounded man who has had a piece of bone borrowed from his leg to mend his arm is able to get out of bed and walk without trouble ten days after the operation. In other cases I have borrowed a boney fragment to fill in a fractured bone from the longest fragment of the injured bone itself, and in my 'Treatise Upon Human Grafting,' in which I have described the development of grafts in various wounded men, there are radiographs and photographs of the patient to whom I applied this process with perfect results. I have found that the 'autograft,' that is a fragment of bone borrowed from the patient himself always gives excellent results in certain conditions. It is quite possible to graft bone taken from another individual or even from an animal, but under such conditions the result is less certain."

Dr. Voronoff even makes the startling statement that it is quite feasible to borrow bones from dead men to mend those of the living, since the death of the individual through the stopping of the heart and the cessation of the circulation of the blood does not cause the immediate cessation of life in all the organs. These continue to live for a certain length of time before decomposition sets in, the period varying with the delicacy of the structure. Dr. Voronoff states that bone survives for eighteen hours after the general death and when removed before this time has expired, it retains all the properties of the bone cut from the living individual, and may be used to repair fractures in the wounded man. He says:

"Bones of animals can likewise be employed, and some ten years ago I was able to transplant a piece of bone cut from the shoulder blade of a sheep under the influence of chloroform into the skull of the patient whose occipital bone had been partly destroyed by a tumor of the brain. After removal of the tumor the breach in the bone was filled in in this manner, and six months after the operation the skull was in perfect repair. In this case, however, I was able to prove that the sheep bone did not form a true graft upon the human bone, but that it was little by little dissolved and absorbed; but as fast as the cells of the sheep bone disappeared they were replaced by osseus cells coming from the human bones in the midst of which they had been implanted. The bone of the sheep, therefore, served merely as a scaffold which the human bones made use of in order to construct the now bone. It is possible, therefore, to make use of the bones of animals as a provisional living substance in order to form a sort of bridge between human bones, by means of which the cells of the latter may eventually join each other and become solidified."

It is very important, however, says the surgeon, that the tissues should be healthy in order to secure the success of

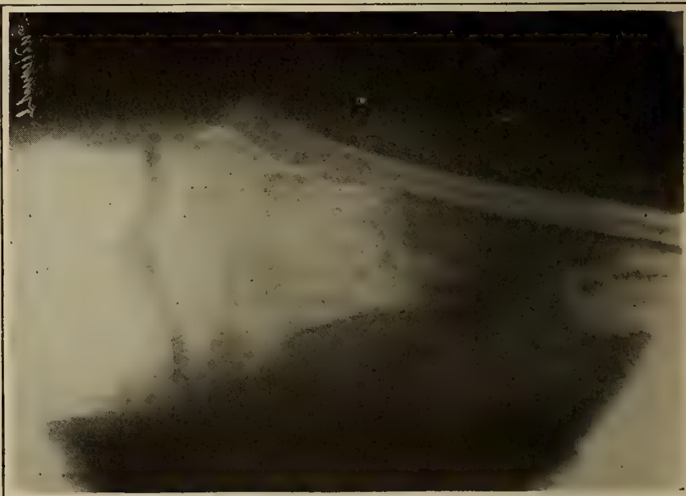


FIG. 2. X-RAY PICTURE OF FIG. 1 SHOWING LOSS OF BONE

the graft. Unfortunately, wounds received in battle are always infected, and while in this condition the transplanted fragment of bone will itself begin to suppurate, hence no attempt at grafting should be made until the wound is completely healed, and there is not the slightest particle of pus remaining. Even so the graft cannot be undertaken immediately since it has been proved that even the healed wound retains within its depths for several months thousands of latent microbes, which are capable of being revived and producing fresh suppuration if the old wound is opened too soon. Dr. Voronhoff states that his experience has shown that it is necessary to wait from eight to twelve months on an average after the wound has been healed before attempting the graft.

It is also very important that the transplanted bone should be placed within the breech without the help of any foreign body, such as metal plates, wires or hooks. This is done by cutting the transplanted piece longer than the breach to be filled and splicing its ends into the ends of the broken bone. By proceeding thus excellent results are obtained. Dr. Morestin, who specializes in wounds of the face, has obtained really remarkable results by the grafting of bone and cartilage taken from the ribs, thus rebuilding broken jaw bones, and replacing the bones of the nose and eye sockets, etc. Skin grafting is also frequently practiced among wounded men who have suffered the loss of large areas of skin. Without skin grafting many months would be required for the healing of such wounds, and the wound would then be covered with thin hard scar tissue lacking the flexibility and elasticity of the true skin. Moreover, said scar tissue often produces retraction of the limbs, giving them awkward and painful attitudes, or it may press upon the sensory or motor nerves in such a way as to cause inertia or interfere with the movement of the limb. Skin grafting on the contrary enables the surgeon to produce a smooth flexible perfect cutaneous covering in a comparatively short time. Dr. Voronoff has made use of skin grafting particularly for covering the stumps of legs which had been amputated in the ambulance. Such amputation is often done by the blow of an axe, leaving the stump quite uncovered by skin. In such cases after several months of suppuration the stump is covered by a thin and uneven layer of skin tissue, which is very sentitive and badly adapted to support an artificial limb. By means of skin grafting these large wounds can be completely covered with supple thick colorless skin in two weeks or less.

Dr. Voronoff states that he has not yet made a graft of a joint, although there are many cases where wounded men have had the joint entirely destroyed, and where the use of the limb might be saved by the transplanting of a joint from a recently deceased corpse. But since such an operation would be unusually delicate and difficult, it is necessary to experiment upon animals before attempting to practice upon human

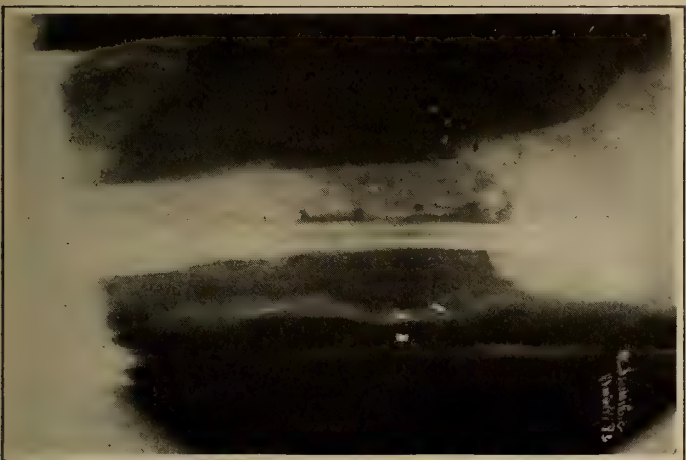


FIG. 3. X-RAY PICTURE ONE MONTH LATER, SHOWING AUTOGENOUS GRAFT TAKEN FROM TIBIA OF THE RIGHT LEG

subjects. A very large number of such experiments were made by Dr. Voronoff during a period of a year at the Physiological Station of the Collége de France, and were described by him before the Bioligical Society of Paris. Dogs which had had a new foot joint grafted on were able to run, walk and jump six months later without anything to indicate that they had a new joint instead of the original one. On examination the articulations were found to be quite supple and well nourished by the blood vessels of new formation. The cartilage was flexible and movement perfect. "These happy results permit us to hope," says the surgeon, "that we might benefit our wounded men in similar manner. But none of these grafts, whether of bones, joints, skin, tendons or nerves, can be applied on a large scale until after the war, since, as I have stated, the wound must be entirely free from ancient septic centers. Moreover, these grafting operations should be undertaken only in hospitals into which patients with suppurating wounds are not received. Since the transplanted fragments have diminished vitally until they form the proper connection with the blood vessels of the new organism, the slightest infection will cause them to die."

While there are many thousands of men crippled by the war, this eminent surgeon holds out the glorious hope that

FIG. 4. RESULTS OBTAINED, SHOWING SCAR OF VORONOFF'S INCISION

a large majority of them may be restored to active life by such operations as he has here outlined. He says finally:

"During the war the most urgent cases only can be treated. Above all the lives of the wounded men must be saved; but after the war it will be our task to restore those men to health and usefulness. Ten years of continuous effort will be necessary to combat and modify the subsequent effects of wounds. Functional re-education and physiotherapy will certainly be of great service, but it will be grafting which will be most important of all. Bones will be grafted on to reconstruct jaws and eye sockets, and to make legs and arms serviceable; jaws will be grafted on to replace those which have been destroyed; skin will be grafted on to remove the disfiguration due to scars; tendons will be grafted to remedy contraction of the fingers; nerves will be grafted to cure paralysis of the limbs, and teeth and hair will be grafted to re-establish the harmony and beauty of the organism. Modern science can and must be bold enough to undertake this task. Humanity in its ascending evolution acquires new creative forces, and we shall become more and more the masters of our own bodies."

CURING SPANISH INFLUENZA WITH TURPENTINE.

The so-called Spanish influenza whose ravages have been general in America as well as in Europe, and which is said to have claimed more victims among our own troops than all the deadly missiles of the enemy, has naturally been a subject of much discussion among medical men the world over. As usual the doctors do not always agree. In a report read before the French Academy of Medicine, Dr. Bezançon made the statement that the pneumococcus is the microbe principally concerned. A fortnight later (August 27, 1918), Dr. Orticoni and Dr. Antoine declared before the same body that in a certain grave cases, at least, the present epidemic may be regarded as a new malady, characterized by the presence in the blood of a peculiarly resistant variety of Pfeiffer's bacillus. Since Dr. Orticoni is the director of the laboratory of epidemology in the French Army, and Dr. Antoine's office is that of consulting physician, they are probably correct as to the most fatal form of the disease. It is gratifying to learn that a new and simple form of treatment has been marvellously successful in curing the most severe and apparently hopeless cases. This treatment consists in the injection of

a few cubic centimeters of pure turpentine into the flesh of the patient. Solid masses of muscle, such as the thigh or the calf of the leg are selected for the operation. The immediate effect produced by the turpentine is the appearance of large aseptic abscesses which cause a so-called "fixation" of the deadly germ. Whatever the mechanism of the curative action of the turpentine, the results are said to be truly marvellous.

Strictly speaking the remedy is not new though the present application is a fresh revival. According to Francis Marre, writing in *La Correspondence* (Paris), Professor Fauchier of the University of Lyons made a practice of the systematic injection more than twenty-five years ago of turpentine into the thigh or the calf of patients suffering from serious cases of pneumonia or septicemia, explaining to the students who atended his clinics that he did this for the purpose of causing the formation of aseptic abscesses of fixation or of derivation.

HOW AGE AFFECTS THE RESPIRATION OF LEAF CELLS.

A FRENCH botanist, M. Maurice Bézagu, has recently been making some studies of the interchange of gases or "respiration" of the cells of leaves and has made the interesting discovery that this process is affected by the age of the leaf. At the meeting of the French Academy, September 22, 1919, he made the following report of the results of his researches upon this question:

The various plant physiologists who have devoted themselves to the study of this question have reported the respiratory intensity of the carbon dioxide liberated during one hour, as being equal to 1 gr. of "cool" weight. They have thus proved that the respiratory activity steadily decreases as the leaf develops. The same thing is said to be true of the ratio $\frac{CO_2}{O_2}$ of which M. Nicholas has recently made a study (*Revue Générale de Botanique*, Vol. XXX, No. 335, 1918).

I have undertaken in my own researches to report the respiratory intensity, not in the gram-hour, a purely physical unit, but in the physiological and histological unit, the cell, during its respiration for a period of one hour. To this end I have related the respiration to the organ-hour, previously formulating the following hypotheses:

1. Two adult leaves of the same species and having surfaces practically equal possess the same number of cells.

2. This number is the same as that of the young leaves which have not yet attained their final dimensions, but in which cellular division has completely ceased. This latter supposition may be regarded as highly probable if we confine our observations to species in which it has been shown that the leaf develops very regularly and reaches, as a general thing, an area of surface which is practically always the same when in the adult state.

I have taken as the subject of my experiments the leaves of the *Robinia pseudacacia, Pinus silvestris, Coboea scandens, Ligustrum vulgare, Althoea, Loroglossum hircinum, Cercis siliquastrum,* and obtained the following results:

1. The respiratory intensity of the cell, which is very slight in the young cells, steadily increases up to a certain maximum which corresponds practically to the moment when the leaf attains its full development; as the leaf ages the respiratory intensity gradually decreases.

Thus at 28°C. a leaf (having six leaflets) of *Coboea scandens*, weighing 0.105 gr. liberates 0.147 ccm. of carbon dioxide; an older leaf, weighing 0.995 gr., liberates 0.499 ccm., an adult leaf weighing 1.757 gr. liberates 0.548 gr., and finally an old leaf, weighing 1.512 gr., liberates only 0.453 ccm. The quantities of oxygen absorbed equal respectively 0.143 ccm., 0.626 ccm., 0.703 ccm., and 0.629 ccm.; these figures form a curve of the same outline as that which represents the carbon dioxide with the maximum at the same age.

In the same way two opposite leaves of the *Ligustrum vulgare* taken at different nodes liberate in a single hour the following amount of carbon dioxide; for a weight of 0.047 gr. 0.014 ccm., for 0.440 gr. 0.119 ccm., for 0.860 gr. 0.218 ccm., and for 0.972 gr. 0.186 ccm.

In relating these results to the gram we are able to verify the known results, namely, that the respiratory intensity decreases with age.

2. The respiratory quotient of leaves, which is very slight when they are young increases very rapidly up to a maximum; then it decreases very slowly until the adult state is reached; and finally, it continues to decrease regularly after the leaf has attained its final dimensions.

Thus in my experiments with the *Robinia pseudacacia* $\frac{CO_2}{O_2}$ starting at 0.60 increases up to about 1 (in one case it was 1.04 and in another it was 0.99), then decreases by very slight amount for leaves taken at successive modes.

The *Loroglossum* shows the same rate of progress but the maximum is only 0.68 while in the *Ligustrum* it is 0.84.

It is evident, therefore, that there is a maximum in the variation of the respiratory quotient, a result which had not hitherto been shown by any authority. There are doubtless two reasons for the failure to note this fact on the part of previous observers—in the first place they failed to experiment with leaves sufficiently young, whereas it is only the very young leaves in which it is possible to observe the abruptly ascending portion of the representative curve; and secondly, investigators have ordinarily conducted their experiments upon only two classes of leaves—young leaves and old leaves, thus having only two points of observation in each series of experiments, a number insufficient to determine the curve.

It should be noted that the respective maxima of the intensity and of the respiratory quotient correspond to very different periods in the evolution of the cell; the first, in fact, is attained by the foliary cells which have fully reached the adult stage, while the second is manifested in very young leaves, in the bud, or shortly after the opening of the latter.

SUGAR AND ALCOHOL FROM THE NIPA PALM.

THE *Bulletin of the Manila Bureau of Sciences* has recently published an interesting account of the possibilities for the production of sugar and alcohol which reside in the Nipa palm which grows in marshy territory and near the mouths of rivers occupying vast areas in the vicinity of Manila Bay and along the coast of other Philippine provinces. The leaf of this palm is used for roofing the huts of the natives, while the fruit is eaten either raw or preserved.

No incision is made in the tree until it has reached the age of five years. The juice is then collected through a period of six months, from July to December, in bamboo tubes holding two liters each. It is estimated that 86,000 liters of juice per hectar can be collected since one hectar will grow 2,000 trees, each yielding about 43 liters. From this amount of juice the minimum yield should be 5,000 liters of 95 per cent alcohol. According to the Far Eastern Review, Mr. Gibbs, a chemist associated with the Bureau of Sciences, predicts a most important commercial future for both the alcohol and the sugar made from the nipa palm.

In the present state of affairs the sugar which can be produced from the nipa is, perhaps, of the greatest interest. In tests made at Manila by Mr. Gibbs, 4 liters of nipa juice subjected to suitable chemical processes, yielded 236 gr. of sucrose, which after boiling and drying produced white crystals of excellent grain weighing 157 gr. and polarizing at 96.8. The molasses upon being boiled yielded 79 gr. of yellow sugar polarizing at 93.8. The second molasses of the same color, measuring 29 ccm., polarized at 58.6. These results in Mr. Gibb's opinion make it certain that the nipa will prove a profitable source of sugar. He estimates that the cost of refining should be considerably less than with sugar cane. Other tropical plants of value, though in a less degree for the production of sugar, alcohol and vinegar are the cocoanut, the buri palm and the sugar palm.

The Arts of Imitation Among Animals

How Far Are They the Product of Instinct and Observation?

EVERYBODY has observed the amusing manner in which young animals imitate their elders. Such imitations suggest the query as to how far they are the product of instinct and to what extent, on the other hand, that of observation. In a recent number of *La Nature*, M. Henry Coupin collates some entertaining examples to show that the latter faculty is frequently employed among various animals. He says:

An excellent method of studying the principle of "imitation" is quite simple, consisting merely in the rearing of certain animals by parents belonging to another species, and then observing the degree in which the behavior of the young ones varies from that which is their by heredity. For example, everyone is familiar with the graceful gesture with which cats lick the paw and then pass it over the face. No similar gesture has ever been observed in dogs. However, puppies which have been suckled by a cat act in the same manner and even borrow various features of their behavior from the male cat. This fact was noted many years ago by Audouin and has since been confirmed by many others. Durau Malle speaks, for example, of a terrier belonging to him which had been raised from the time of its birth with a young cat some six weeks older than itself. Until it was two years old the terrier was not in the company of any other dog and during this time it was accustomed to jumping like a cat, to rolling a ball, to playing with a mouse with its forepaws, to licking its paws, and to scratching its ears. Moreover, it appeared to dislike animals of its own species, and if a strange dog came into the garden where it was it chased the latter promptly away. Another observer, Prichard, also mentions a dog which had been raised by a cat and had been taught by its foster-mother the art of licking its paws and washing its face. Dr. Routh also cites the curious case of his own dog, a King Charles spaniel, which had been suckled and reared by a cat from the third day of its birth. Like the cat the spaniel was afraid of rain and would turn aside from its path to avoid a damp spot in the road. It sat upon its tail as cats do, licked its paws two or three times, and then washed its muzzle with them. It would likewise remain for hours together on guard at a mouse hole. . . . Another lover of house animals, C. H. Jeens, tells of his dog which had been nursed by a cat from the time it was a month old, and which not only was in the habit of killing mice, but what is far more curious treated them in the same manner, letting them escape and then recatching them repeatedly for several minutes.

Schleitlein speaks of a spaniel which was in the habit of closely watching its master with the evident desire to render him a service . . . ; if his master picked up a ball to play at skittles, the dog likewise seized one and seemed chagrined at being unable to bite it. When his master collected stones for his collection the dog also picked up pebbles. If the master began to dig the dog promptly followed suit with his paws. When his master sat at a window to gaze upon the view the dog leaped up beside him and likewise gazed out. When he saw his master or the cook carrying a stick or a basket the dog made known his desire to do the same.

K. Groos considers it to be evident—though the matter is disputable—that there is a certain quality of imitation in the howl of a dog which listens to music. "It should be noted," he says, "that a dog who accompanies a piano with his howls is not always forced to listen to the music, but remains in the room of his own accord. I am very far from believing that the howl of the dog is always a sign of displeasure—as a matter of fact it is just at this time, that is, when he accompanies the music with his howl that it seems to me that he uses his voice with the most pleasure and zest. One might also mention certain isolated cases in which there may be thought that there was even an imperfect imitation of the air. However, it is easy to be the victim of an illusion as regards this. One of my friends, the curé A. Freiber, living near Eppingen, possessed when a student a female spaniel, named Rolla, which he was accustomed to exhibit to his friends. When, for example, he sang the Lorelei in a falsetto voice the dog accompanied the air with howls and one soon became able to perceive quite plainly that the voice of the dog followed the varieties of the tones in some degree. . . ."

The spirit of imitation is still better developed in monkeys . . . examples of this are abundant. We will cite one which is not very well known, related by Fr. Elleendorb, concerning a small black monkey with a white head from Costa Rica. "The first day that he was in the room, he seated himself in front of me at the table and examined everything he found. He finally came across a box of matches which he soon succeeded in opening. He smelt them and threw them upon the table. I picked up one, lit it and showed it to him. He opened his small eyes wide with astonishment and gazed at the flame fixedly. I lit a second and a third and handed them to him. He held out his hand hesitatingly, took hold of the match, held it before his face and gazed at it with astonishment. When the flame came near his fingers, he threw the match down. I closed the box and put it upon the table thinking he would immediately take possession if it. But he seated himself opposite it and looked at it and smelt it from all sides without daring to touch it; then he approached me, rubbed himself against me and made signs full of astonishment as if he said "What is that?" He next returned to the box, turned it every which way and finally succeeded in opening it, but carefully avoided touching the matches. He seemed anxious and doubtful, walking around the box, and then returning to me as if to make some inquiry. I lit a match and handed it to him. When it had burned out he took one himself, scratched it upon the cover of the box, and turned the latter upside down. Shortly after he turned the box over again with the prepared side on top and scratched another match, but since he had seized the match from the wrong end I turned it for him; he then began to scratch it on the box until it caught fire whereupon he exhibited great joy and excitement. He thereupon seized a handful of matches and scratched them upon the cover until they lit."

Romanes' sister tells another story worth quoting with regard to a brown capuchin monkey. "One day when he had broken his chain he went up to a box in which nuts were kept for him, looked for the key and fingered the lock, whereupon I handed him the key. For the next two hours he tried to open the chest, but the lock was a little bit strained so that in order to open it it was necessary to lean on the cover; for this reason I thought it would be impossible for the monkey to open it. He finally succeeded in getting the key into the keyhole, turned it in both directions and after each attempt endeavored to lift the cover. All this was evidently the result of his observation of human beings as is shown quite plainly from the fact that after each failure to get the box open, he fumbled about the lock for a number of times with the key. This is explained by the fact that my mother, owing to her poor eyesight, was obliged to fumble with the lock a number of times before being able to insert the key. The monkey evidently believed that this fumbling was indispensable, though it was quite useless so far as he was concerned, as he was perfectly able to insert the key in the lock.

Among other examples of imitative acts might be cited sheep . . . elephants (in which case domesticated animals are employed to educate wild captives), many bears, martens, parrots, etc.; but the instances given above are sufficient to call attention to the matter and engage the interest of the observer.

Artificial Parthenogenesis and Cell Stimulants*

Similarity Between the Regeneration of Wounds and the Phenomena of Reproduction

By Prof. Dr. Methodi Popoff

The author of the present article is a well-known authority upon cell study. At the time of writing in February, 1916, he was one of the physicians on the staff of the Bulgarian Military Hospital No. 1, at Skopje in Macedonia. Through a coördination of the observations here made by him upon the wounds of soldiers with the results of his previous study of the functions of the germ-cells and the somatic cells and of the phenomena of parthenogenesis, he came to the remarkable conclusion that the regeneration of wound tissues is similar in character to the regeneration of the germ cells, which results in reproduction. He furthermore declares it to be his belief that in both cases, i. e. in the regeneration of the somatic cells as well as that of the reproductive cells the same cause is operative, namely, the stimulation of the cell. In the present study he gives a masterly resumé of the work done by such eminent authorities as Loeb and Delage with respect to artificial parthenogenesis, adding thereto a description of his own experiments and observations by means of which he was led to the profoundly important conclusion that all cells whether the somatic tissue cells of the individuals or the reproductive cells, and whether animal or vegetable, are alike subject to the same law of periods of depression and can alike be aroused from such depression by means of a great variety of stimuli.—Editor.

The close observation of the life processes of the free-living cells has made known to us peculiar conditions occurring therein under which the physiological functions of the cell undergo a disturbance—coming indeed to an almost complete cessation of function—and then after the lapse of a certain period of time resuming their normal course. These conditions of retarded functioning—the conditions of depression as they have been strikingly called by Calkins—are particularly easy to perceive in the protozoa (Maupas, Hertwig, Popoff, etc.) just before the commencement of the sexual processes. The latter usually begin to make their appearance precisely during the period of the so-called "senile degeneration" (Maupas) of the cells, in other words, the period of a physiological depression (Hertwig). Through the beginning of the sexual processes or else through other regulating processes, the cells suffering from depression are rejuvenated and have their vital capacity restored.

Starting from this basis I have expressed the opinion in a number of publications that the aforesaid physiological condition is not only characteristic of the free-living cells, but also of the sexual cells of the metazoa, *i. e.*, that the cells of all those organisms of a higher order than the protozoa are also subject to a similar physiolgical depression. As a matter of fact when we examine more closely the processes of development of the sexual cells, or germ cells, of the metazoa, we are immediately struck by the fact that after a series of complicated alterations the germ cells finally arrive at a peculiar physiological condition, in which condition there is a disturbance of their vital processes. This disturbance finally becomes so great that the sexual cells, even under the most favorable conditions, finally and inevitably perish. The sexual cells die through the mere alteration undergone by every cell of the organism which has ended its course of life; in other words, the sexual cells perish through a profound physiological depression.

The exception of this vital process of the germ cells exhibited by the normally parthenogenetic ovules or "eggs" is only *apparent*. It is true indeed that such eggs exhibit great tenacity of life throughout an entire series of generations, since they constantly produce new generations without the intervention of the regulating process; however, even in the case of these cells conditions finally arise which cause them to be incapable of further spontaneous development. When they arrive at this phase of their development they die, by reason of a profound physiological depression, in the absence of any regulating process.

This course of the life of the germ cells—whether they be protozoan cells, differentiated sexual cells of the metazoa, or normally parthenogenetic egg-cells—indicates that these cells, exactly like the somatic cells of a many-celled organism are subject to conditions of depression, which in the absence of regulating processes result in the degeneration and the death of all these cells.

One of the regulation processes which normally makes its appearance in the sexual cells is fertilization. When fertilization occurs the germ cell whose death is otherwise inevitable receives an impulse to evolution, and thus by reason of its latent potentialities gives rise to a new organism.

At the present time, however, we are familiar with cases in which egg-cells which normally require to be fertilized become capable of development without any previous fertilization. The name of artificial parthenogenesis has been given to such phenomena. It has been proved by numerous observations and experiments that the regulating physiological effect of fertilization can be almost entirely replaced by an extremely large variety of agents and that by such means those cells which are in a state of profound depression can be made once more capable of life and development. This brings us to the crux of our present question. Hence I will here develop somewhat further the ideas expressed in my volume entitled "*Experimentellen Zellstudien* IV."

In 1886 Tichomiroff treated unfertilized *bombyx* ovules for a period of two minutes with acids such as hydrochloric and sulphuric acid or with purely mechanical stimuli such as friction, agitation, etc. The ovules thereupon began to exhibit segmentation, beginning to produce small embyros. A your later O. and R. Hertwig succeeded in producing the first stages of segmentation in the ovules of the *Strongylocentrotus* by the application of certain chemicals (chloroform in 1887 and strychnine, by R. Hertwig in 1896). These observations furnished a starting point for a thoroughgoing investigation as to the nature of the agents capable of producing the development of unfertilized egg-cells. It was found that artificial parthenogenesis can be produced by the most various kinds of influences—for example, by the action of the chlorides of potassium, sodium, magnesium or manganese, by carbon dioxide by ammonia, by tannin, by various fatty acids, by sperm extracts, by serums, by treatment with xylol, with toluol, ether, etc. Furthermore, the alteration of the osmotic pressure of the surrounding medium, the abstraction of water, and the most extensive variety of mechanical influences were also found to be highly effective agents in the production of artificial parthenogenesis.

The effect of some of these agents as, for example, that of the hypertonic solutions of alkaline liquids, or of the abstraction of water, etc., upon the egg is so favorable that the latter can thus be stimulated to continue its development far beyond the larval stage. As a matter of fact Delage succeeded indeed in producing young sea-urchins by purely artificial parthenogenesis.

*Translated from the *Biologisches Centralblatt* (Leipzig) of April 20, 1916.

The widest variety of opinions prevails concerning the nature and manner of the operation of all these agents upon the unfertilized egg-cell and with respect to the underlying causes of the phenomena of artificial parthenogenesis. The first experimenter along these lines, Tichomiroff, is of the opinion that the egg-cell is capable of responding to all stimuli whatever, no matter what their nature, only through a single specific reaction, namely, segmentation. Other authorities, Bataillon, Matthews, as also, and still earlier, Loeb, Delage, etc., consider the abstraction of water from the egg-cell by means of hypertonic solutions or merely through the simple allowing of the egg to dry out, as, for example, when placed upon filter paper (Giard) to be the most decisive stimulus in the production of the evolution of artificial parthenogenesis. These investigators hold with Matthews that in normal fertilization likewise, the abstraction of water from the protoplasm constitutes the original cause of the beginning of segmentation, since it is a well known fact that both the male and the female pro-nuclei increase in size during their growth by the absorption of liquid from the surrounding protoplasm.

Other explanations that have been suggested as the cause of artificial parthenogenesis include also the action of the ions of the reagents employed upon the egg-cell (Loeb), the effect of the alkalinity the alteration of the peripheral layer of the egg-cell by the alkaline and lipoid-dissolving reagents, the enzymic effect of the sperm extract, etc.

From this multitude of attempts at explanation two have recently come into especial prominence, mainly, those of Loeb and of Delage—theories which at first glance lie far apart.

Loeb takes as a starting point the following observations: experiment has proved that hypertonic solutions exert a strongly stimulating effect upon the vital processes of the egg-cell—in other words they are remarkably effective parthenogenetic agents. However, the cells produced though the segmentation of the artificially fertilized ovule would separate from each other and perish if other stimuli failed to appear. The cells produced by segmentation are held together by the formation of an egg-membrane. In the process of the artificially induced development the formation of this egg-membrane can be brought about by the brief action of reagents capable of dissolving lipoids and fats. By means of this process a portion of the superficial lipoid and fat-layer of the egg is dissolved, the space thus formed by the exudation from the plasma is taken up and in this manner the yolk-membrane which is characteristic of the fertilized *Echinidus* egg is formed. The dissolved lipoid substances are employed for the nuclein synthesis which begins to take place energetically in the process of segmentation. Basing his experiments upon these observations Loeb has succeeded in fact in producing an extremely effective compound of chemical agents—namely, fatty acids and hypertonic solutions (chloride of magnesium)—by means of whose use almost 100 per cent of the eggs treated were induced to develop, continuing this development beyond the larval stage. Delage's method of producing parthenogenetic development, which is likewise highly effective, inducing the development of practically 100 per cent of the eggs treated, is based upon very different observations. According to this authority living substance is a complex of albumens which compose a coloidal solution in an electrolytic liquid medium. This colloidal complex is in an unstable condition, so that the soluble phase and the jelly phase are each near the critical point. The segmentation of the cell is characterized by coagulation (*i. e.*, the passing over into the jellied condition, the formation of the chromolones, the appearance of the mitotic figure, etc.) or by the solution (*i. e.*, the dissolving of the nucleal membranes, etc.) of some of these albumens. In Delage's opinion, therefore, it must be possible to induce the segmentation of the cell by influencing a cell which is in a state of equilibrium with chemicals which are capable of producing the series of colloidal transformations which are characteristic of the segmentation of the cell. Delage employs ammonia as an agent of solution and tannin as an agent of coagulation. By the influence of these agents the transformations of the colloidal substance are once more set in operation and the cell consequently proceeds with its segmentation uninterruptedly.

All the theories here mentioned strive to indicate those stimuli which in the opinion of the authors are common to normal development and to that of artificial parthenogenesis. These theories take as a basic principle the concept concerning the physiological condition of the sexual cells which is today so widely accepted—namely, that in the organism the sexual cells are those which have the greatest vital capacity, but which in spite of this are subject at the end of their development to a remarkable physiological condition of equilibrium or rest. Just as the fertilization and the consequent transformations of the egg-cell forms a complex of phenomena limited to this, so likewise the effects of the above-mentioned agents of artificial parthenogenesis produce specific phenomena comparable to the normal processes of fertilization and are applicable only to the sexual cell.

Let us now enquire whether this manner of looking at the matter can be really correct, and whether it can be made to agree with our knowledge of the general physiologic nature and conditions of the cell.

As I stated at the beginning of this article—an idea which I have treated more extensively in former works—every cell in the entire organism arrives in the course of generations at a peculiar physiological state in which the vital functions greatly decline. This decline leads, little by little, to a gradual siesta or retardation of the phenomena of life, and finally, from purely internal causes, to the death of the end generation of the series of cell chains concerned. The sexual cells do not escape these functional disturbances any more than other cells. However, the sexual cells . . . possess the power to rejuvenate themselves through a fundamental reorganization and again to bcome capable of growth and division. This regulating process is brought about by means of fertilization.

According to this point of view how shall we regard the action of those agents which have shown themselves capable of producing artificial parthenogenesis? As I have already said, the mature germ cells have arrived, according to the theory here enunciated, at a condition of depression of their vital functions. By means of the action of all of the above mentioned changes the germ cells are rejuvenated. They are subjected to a process of physiologic regulation and in this manner they are again made capable of exercising their vital functions. In so far as the process of artificial parthenogenesis is a process of cell rejuvenation it is comparable to normal fertilization. Therefore, artificial parthenogenesis must also be a mere phenomenon of cell physiology falling within the dominion of rejuvenation phenomena of the cell, and, as such, being of the greatest importance in general with regard to our concepts of cell physiology.

It is true that a different cell makes its appearance in the further development of the rejuvenated germ cells and the rejuvenated somatic cells. The germ cell (of non-differentiated tissue) which is endowed with all the potentialities of an organism, must necessarily, as a final result of its segmentation occasion the formation of a new organism. Whereas the ordinary tissue cells produce during the process of division, in the course of regeneration, for example, merely a specially differentiated kind.

Starting with these theories I undertook a series of experiments to support them, which I will here describe. In order to avoid repetition I will refer the reader to earlier publications of mine (*Experimentelle Zellstudien IV*, *Arch. f. Zellforsch*, 1915, *D. Med. Wochenschrift*, 1915, No. 42).

I. Numerous researches concerning artificial parthenogenesis have shown that the hypertonic solutions of the chlorides of sodium, magnesium, potassium, manganese, etc., exert a very favorable regulating and stimulating action upon the germ cells. These experiments show further that the success

of such treatment depends not only upon the hypertonic nature of the solutions but also upon their chemical composition —for not all hypertonic solutions are equally effective. There is a marked superiority in the favorable stimulating effect upon the mature egg-cells in hypertonic solutions of sodium chloride (salt) and magnesium chloride. The percentage of development obtained from eggs treated with these solutions is almost one hundred.

According to the hypothesis here stated, however, such hypertonic solutions must exert a general stimulating effect upon all the cells of the body, and not a merely specific effect confined to the germ cells alone. In order to test this theory, I made the following experiments: It occurred to me that a very satisfactory object for my first test was afforded by plants in the condition of their winter rest. If it were found possible by this means to induce plant cells in a condition of rest to undergo a premature development, this would furnish a proof that the above mentioned hypertonic solutions exerted a stimulus upon cells in general. As a test plant I made use of sprigs upon an elder bush (*Syringa vulgaris*), since this plant, as I knew from earlier experiments, is more easily influenced than others.

On January 18, 1916, I took from the same branch three sprouts, whose winter buds were still closed. In one of them I injected immediately beneath the two end buds a 40 per cent hypertonic solution of magnesium chloride (about ¼ ccm.). In the second sprig I injected in the same manner and at the same place a 40 per cent solution composed of 20 per cent of sodium chloride and 20 per cent of magnesium chloride. A third sprout remained untreated and served as a control. All three sprouts were placed in the same glass which was filled with spring water and were kept at the temperature of the room, which varied from about 20° C. by day to 10° C. at night.

At the end of a week a distinct difference was observed in the behavior of the control and that of the two twigs being experimented upon. The former remained almost unaltered, while the twigs which had received the injection had swollen and their protecting scales had spread apart. On the seventh day the injections were repeated in the same manner. Each following day thereafter showed a greater difference between the control and the other twigs. The latter were entirely opened out both at almost the same time, and on the 9th day showed the tips of the flower buds. On the 14th day as shown in the accompanying illustration the experimental twigs had already reached a considerable degree of development (I and II), whereas the control (III) had increased in length but showed no open buds.

This experiment shows what a strong stimulating effect is exerted by the hypertonic injections which are employed to produce artificial parthenogenesis upon somatic cells in a state of functional repose, in this case plant cells. My experiments along this line were continued and extended.

I also made use of the experiments of Weber, Jesenke, etc., to support the results of the experiments just described. These authorities likewise caused a premature sprouting of buds by means of injections of weak solutions of various salts (salts of sodium and of magnesium).

This strikingly stimulating effect of the hypertonic solutions of the chlorides of magnesium and of sodium suggested that it would be highly desirable to test their effect upon the regeneration of wounds; if it were true, as supposed in my hypothesis that the agents employed to produce artificial parthenogenesis did not confine their action to the germ cells alone, but behaved as cell excitants in general, then their effect would be to produce a more rapid regeneration of wounds. The experiments made by me along this line gave very satisfactory results.

A—I treated both deep muscular wounds and extensive superficial ones (from 10 to 25 cm. in length and from 5 to 10 cm. in breadth) with a 30 per cent solution of hypertonic sodium chloride. The deep wounds were thoroughly washed with a solution of common salt or, when possible, the wounds were bathed in the hypertonic solution for from 20 minutes to half an hour. Wounds which were at first in an *a-tonic* condition and refused to granulate soon acquired a reddish color while the granular tissue increased in extent and the process of healing was hastened. A few examples will serve to illustrate this:

1. A large round wound of the heel 5 cm. in diameter after making some progress towards healing came to a stop. The muscular tissue was *a-tonic* and pale and refused to granulate or form epithelium. The wound remained for six weeks in this stationary condition. On January 28, a hypertonic sodium chloride solution containing also 0.5 per cent of potassium chloride and calcium chloride was applied. Shortly afterwards the wound assumed a red color and began to granulate. On February 10, it was entirely healed and covered with epithelium.

2. This patient had a fracture of the humorus from a gunshot wound; he was operated upon for the second time on January 10. There were communicating wounds upon the inner and the outer side above the elbow. The wound was treated with a hypertonic solution of sodium chloride on January 10. On January 25, the communication between the wounds was closed. The outer wound filled up but there still remained a spot about 10 cm. long and 4 cm. wide which was not covered with epithelium. The inner wound, having a diameter of 4 cm., still led into a canal about 8 cm. in depth from which there was a flow of pus. It was treated with a hypertonic bath of common salt. On February 2, this wound also healed nicely without pus. On February 14, both wounds were closed and covered with epethelium.

B—Wounds treated with a solution of 15 per cent of magnesium chloride and sodium chloride also exhibited early granulation and formation of epithelium.

1. This patient had a bullet wound in the ankle, both the tibia and the fibula being perforated. On January 26, the front wound was torn open to an area of 10 cm. long and 8 cm. wide; it was in communication with an equally large wound on the inner side of the ankle. Both wounds were suppurating. They were first washed with hydrogen peroxide and then bound with a very wet compress (a solution of magnesium, chloride, and sodium chlorides) for half an hour. On February 6, the communication was interrupted, there was no suppuration, and the wounds were rapidly granulating and had become almost superficial. On February 12, the wounds were almost closed, only a long narrow strip not covered with epithelium remaining. On February 20, the wounds were entirely healed.

2. This patient had a fracture of the left femur in November. There was a second operation on January 10. There was a deep wound 10 cm. long and 10 cm. deep on the front of the thigh; at the rear of the thigh there was a separate wound widely torn, 20 cm. long 6 cm, broad and 8 cm. deep. Both were suppurating. On the first day, January 26, after the treatment with magnesium chloride and sodium chloride, the suppuration increased and the pus was mixed with blood. On February 2, the rear wound had ceased to suppurate and was rapidly granulating. Pus still came from the front wound but was mixed with blood. From time to time the wounds were washed out with hydrogen-peroxide and then again with the solution of the chlorides of magnesium and sodium. The wounds continued to granulate and on February 8 the rear wound was in a very good condition being 4 cm. long and 3 cm. deep. On Februay 22, the rear wound was closed while a small opening leading into a canal 5 cm. deep still remained.

C—Equally favorable effects with regard to wound regeneration followed the application of the 30 per cent solution of magnesium chloride alone.

[*The author here describes three cases of serious wounds thus treated whose details it is unnecessary here to mention, though it may be remarked that in one case there were particularly remarkable results with respect to the healing of*

frozen tissues, which usually are very slow to recover.—EDITOR.]

In all these cases, as in others which will be referred to later, there was almost no medium employed of an antiseptic and tissue killing character. Only the wounds which were strongly suppurating were first washed out with hydrogen-peroxide and immediately thereafter treated with a hypertonic solution. It should be remarked, however, that in some cases the magnesium chloride alone was not so favorable, being slower in action. . . . The favorable effect of this solution is especially marked in clean wounds which can be allowed to granulate and heal.

All these experiments indicate that the hypothesis expressed above with regard to the general effect as a cell stimulus of the hypertonic agents employed to induce artificial parthenogenesis is correct.

II. This hypothesis is strongly supported by the coincidence of the phenomena exhibited in artificial parthenogenesis and those of cell stimulation observed in experiments in which plants are subjected to the influence of ether. Molisch, Johansen, Weber, et al. have found that buds in a state of repose can be induced to sprout earlier when treated for a short time with the fumes of ether . . . the effect of ether as a stimulant to development is so marked in fact, that it has been successfully used in the art of horticulture. But ether is also an agent for producing artificial parthenogenesis (Matthews, 1900), and is, therefore, to be regarded as a general cell stimulant. This naturally suggested to me to test its effects upon the regeneration of wounds . . .and experiments along this line met with surprisingly successful results. Since the use of pure ether or ether fumes upon wounds is inconvenient I employed one part of ether mixed with three parts of sterilized olive oil. This mixture of oil and ether was either applied directly to the wound or else the wound was covered with a gauze bandage thoroughly saturated with the mixture, the bandage being changed daily or every other day. The wounds treated by me in this manner were mostly cases of freezing, *i. e.* just those wounds which as a usual thing granulate very slowly and heal with difficulty.

Shortly after the beginning of the ether treatment, soon after the application of the second or third bandage, the wound was seen to turn red; shortly afterwards a healthy looking granulation tissue appeared and was soon followed by revivification of the surrounding layer of epithelium. After a short lapse of time, even after two or three weeks, very large wounds, which had previously made no progress for weeks or even months, frequently closed . . . it may be stated in fact, that the results obtained by the oil and ether treatment were the most remarkable in my whole series of experiments.

[*We have not space to describe the striking results here given in detail in the case of four wounded men.*—EDITOR.]

III. *Mechanical Stimuli.*—Tichomiroff showed that silkworm eggs can be incited to develop when mechanically irritated by brushing, stroking, shaking, etc. By agitation alone Matthews also succeeded in 1901 in inciting the development of *Asterias eggs* up to the bipinnary stage. Consequently, mechanical stimuli have also been regarded as a specific agent in the production of artificial parthenogenesis. I uphold this view. It is a matter of daily observation that callosities such as corns, the finger callouses of writers, etc., are formed at points where the cells are frequently subjected to mechanical irritation: this mechanical stimulus causes the cells to begin to divide, thus forming epithelial or dermal proliferations. In such cases the effect of mechanical irritation as a cell stimulant is obvious. And it is to this stimulation, I believe, that the favorable effect of general or partial massage must be ascribed. The said stimulation favors the vital functioning of the cells and causes their more energetic segmentation. Consequently, it is cell stimulation which is of primary importance in massage, although it has been hitherto supposed that the latter's effectiveness was mainly due to the increased circulation of the blood and consequent better nutrition of the area in question. But the best circulation is of no use if the cells fail to function properly. . . . If this view is correct then the regeneration of wounds, especially of the epithelium, will be accelerated by cautious local massage near the edge of the wound. My experiments along this line were very satisfactory, the massaged wounds exhibiting an energetic regeneration. I have found it especially favorable to rub the surface of the wounds vigorously with dry gauze. As a matter of fact, this rubbing commonly occurs unconsciously during the cleansing of superficial wounds. . . . It is a striking fact, too, that strictly immobilized arm or leg fractures are much more difficult to heal and the ends of the bones unite much more slowly than when very slight motions and friction—amost imperceptible, perhaps—are given to the area of the fracture by the feeble play of the surrounding muscle. The mechanical irritation of the osteoblasts thus produced stimulates the latter in their segmentation thus producing a more rapid formation of the bone tissue. In fact, this growth is often so hypertropic that there is an irregular thickening about the point where the ends of the bones have knit.

EFFECT OF STIMULATING ELDER TWIGS IN A STATE OF WINTER REPOSE BY MEANS OF INJECTIONS OF HYPERTONIC SOLUTIONS

I Injections of magnesium chloride. II Injections of a mixture of the chlorides of magnesium and of sodium. III Control. Places of injection are indicated at *a a*.

The same idea is supported by the phenomena of skin transference. The wound upon which the piece of skin is to be transplanted is previously rubbed for some time with a sterilized piece of gauze, which has been found to favor the transplantation. . . . To my mind it is evident that the cells underneath the transplanted piece of skin are thus stimulated so as to divide more energetically and thus produce a more rapid union between the transplanted and the original tissue.

IV.—From 1900 to 1910 Bataillon made many experiments in the effort to prove that the most effective stimulus in the production of artificial parthenogenesis is the abstraction of water from the egg plasm. . . . By the action of hypertonic solutions (of salt, grape sugar, animal serum, and the like) upon the egg water is abstracted and segmentation induced. . . . In 1910 he pierced with a very fine metal needle, eggs of the *Rana* and by this simple method produced the phenomenon of artificial parthenogenesis. He believed, likewise, that a similar operation was effected in natural fertilization, namely, the water-abstracting effect of the male and female pronuclei upon the protoplasm. . . . Whether this concept of the matter is correct or not, the important thing from our present viewpoint is that through these operations the egg-cell has its capacity for functioning restored and begins to divide into segments. In my work "Experimenal Studies IV" (1915) I have endeavored to prove that the above mentioned agents of artificial parthenogenesis are not specific, but, on the contrary, general or *universal* cell stimulants. I have endeavored

to explain the physiological meaning of the widely found phenomenon of encystment in the one-cell organisms by this method.

According to this concept encystment must be regarded as a process of cell rejuvenation, and this indeed by means of the abstraction of water from the plasma which takes place in cyst formation. . . . Similarly it has been found that the partial abstraction of water from the plasma exerts a very stimulating effect upon the regeneration of wounds.

[*The following passage, which it is here necessary to omit, gives data in support of this statement, especially with regard to the superiority of the "dry" aseptic treatment of wounds over the moist (with antiseptics) method, except where serious suppuration is present.*—Editor.]

It is in this manner, too—*i. e.* the stimulating effect produced by the abstraction of water from the plasma—that I believe we can explain the favorable results obtained by the dusting of wounds with various powders. For example certain clean superficial wounds were dusted over with amylum powder and bound up dry. They healed rapidly and normally. I find a counterpart to this stimulation of somatic (*i. e.* general tissue) cells in Giard's bold experiment of 1904, when he succeeded in inducing *Echinus* eggs to develop by merely drying them between two leaves of filter paper.

V—Purely out of theoretic interest I am at present conducting certain experiments with respect to the effect of sperm extract upon the regeneration of wounds. . . . Details of these will be published later.

[*In this connection the reader's attention may be called to Dr. Voronoff's experiments concerning the rejuvenation of aged animals by somewhat analogous means.*—Editor.]

VI.—Since we have thus proved that the agents of artificial parthenogenesis likewise exact a stimulating effect upon somatic cells we may surmise that they are also capable of exerting a favorable effect upon the general health of individuals who are sick or feeble. Such results can be obtained in fact by the sub-cutaneous or intravenous injection of solutions of sodium chloride, magnesium chloride, or the mixture of the two described above as shown in experiments on guinea pigs. . . . Such treatment has also been employed with advantage in cases of Asiatic cholera. . . .

FINAL REMARKS.

It is evident from the observations and experiments above set forth that the action of the agents capable of inducing artificial parthenogenesis is not confined to the germ-cells but is likewise exerted upon all other cells. Hence we may regard them as being cell stimulants in general. And this being true we see the immense importance of experiments in regard to parthenogenesis with respect to cell physiology in general. . . . It is equally obvious how important this subject is in energy and in medicine.

And more still! A more profound and cearching investigation of the manner in which cell stimulation is effected will not fail to give us a broader comprehension of the interesting and important problem of age and of the possibility of temporarily, at least retarding the appearance of its phenomena.

We may hope to . . . to have fresh light shed in this manner upon the physiology of the processes of sex, and upon the death of the cell.

THE MOST VALUABLE CROP.

If a man from the Dakotas or Minnesota were asked to name the most valuable crop, he would very likely name wheat; if from Illinois, corn; if from the South, cotton or sugar; but it will surprise many to learn that probably the cocoanut palm is the world's most valuable plant, producing the most important crop. Chemistry has played a large part in making this true, for it is to chemistry that we are indebted for improvements in the refining of cocoanut oil and for the use of this food stuff in butter substitutes, hydrogenated oils, and to replace animal fats in a number of instances. For example, it is a neutral, white cocoanut butter or oil which is emulsified with reconstituted, dry skim milk to produce a cream of any pre-determined fat content for use in confections, baking, and indeed wherever cows' cream is ordinarily employed.

Not only is the oil usually pressed from copra, as the dried meat of the cocoanut is called, an article of increasing commercial importance, but the cocoanut itself has recently greatly advanced in value with the demand apparently unsatisfied. This is largely due to the increase in its use in confections, the demand for candy having grown, as had been anticipated, as the result of prohibition. For example, a plant that had been established to prepare charcoal from the cocoanut shells for gas masks and produce an excellent quality of cocoanut oil from the meats, this having the advantage of being prepared from fresh material rather than from dried copra, now finds itself unable to compete with the prices paid for the nuts to be used in confections.

In acclaiming the cocoanut palm as the most valuable plant, it should be pointed out that in its native land the palm furnishes food, drink, clothing and shelter to the natives. Its fiber is woven into mats and cloth for a great variety of purposes, the tree supplies much of the timber for local needs, the nuts are almost the whole source of fats, if indeed not of food, and the milk of the nut is the usual beverage. In many islands and coasts where the palm forms the basis of all industry, the farms are tiny plots of ground, and there have been instances of litigation concerning the ownership of literally fractions of cocoanut palms situated at the intersecting lines of farm boundaries.

WEED SEEDS.

In view of the research being conducted on the possibility of using various sorts of seeds, principally as a source of oils, it may be of interest to call attention to the article on the weed problem in the Bulletin of the Colorado Experiment Station.

We have come to consider as weeds those plants which grow where they are not desired, plants which resist men's efforts to subdue them, those which resist frost, hail, and dryness, growing in almost any kind of soil and under all conditions, those which have rapid methods for propagation, including the production of great quantities of seeds, and those which are useless or troublesome notwithstanding the fact that they are frequently beautiful. Emerson once said that "a weed is a plant whose virtues have not yet been discovered."

Weeds produce seeds in very large numbers and most of these seeds live for a long time. It has been learned that some seeds, when buried in the soil, may retain their power to germinate for fifteen to thirty years, and in this class can be named the tall pig weed, shepherd's purse, dock, and chick weed.

A large purslane plant will produce 1,250,000 seeds. A single Russian thistle produces from 100,000 to 200,000; tumbling mustard, 1,500,000; and shepherd's purse, 50,000 seeds per plant.

The seeds of many weeds are very small and consequently escape notice. A pound of clover dodder, as well as the common plantain, contains approximately 1,841,000 seeds. Lamb's quarters numbers nearly 605,000 seeds per pound and Russian thistle over 266,000; wild mustard, 216,000, and wild oats more than 25,000 seeds per pound. From this it will be seen that if sixty pounds of wheat are planted on an acre and this seed is contaminated by as little as two per cent of wild mustard seed, there will be distributed over that acre of ground more than 388,000 mustard seeds.

These new facts bring out the necessity for clean seed and the desirability of persistence in eliminating weeds from areas by destroying them before they can bear seeds. However, if the chemist find a way to use such seeds economically, it would appear that there should be no difficulty in obtaining large and constant supplies of raw material.

INSPECTING A LARGE SHIPMENT OF FOREIGN NURSERY STOCK AT THE POINT OF DELIVERY

Our Botanical Immigrants

The Quarantine Regulations of California

Photographs Copyrighted by Keystone View Co.

CALIFORNIA'S horticultural Quarantine service has proved a vital factor in the successful production of plant life in the Golden State, where $255,000 worth of plant products was realized during the past year. The quarantine division, which is under the control of the State Commission of Horticulture, is a public office maintained for the protection of the crops, both agricultural and horticultural produced in the State of California. Through the various ramifications of the quarantine service, it reaches and controls practically every point of delivery in the state, holding as it were a great sieve through which is strained the imports of plant products upon their arrival at every avenue of entrance and by all methods of transportation—rail or mail, land or water, freight, express or personal baggage. Under the direction of Frank Maskew, chief deputy quarantine officer, stationed at the central station in San Francisco, 240 quarantine inspectors are working. They are vested with authority to intercept, examine and pass final judgment upon the health, cleanliness and general desirability of each and all botanical products entering the five ports of entry on the Pacific Coast. They are San Francisco, Los Angeles, San Pedro, Eureka and San Diego.

At the maritime ports of entry the state is represented by ten inspectors and two clerks, and coöperating with the main division at all times by virtue of appointment of state quarantine guardians, and 227 county commissioners and inspectors stationed at the different interior points, each in constant touch with the central horticultural quarantine office in San Francisco. The state quarantine law is in force in every express office, freight depot and wharf in California.

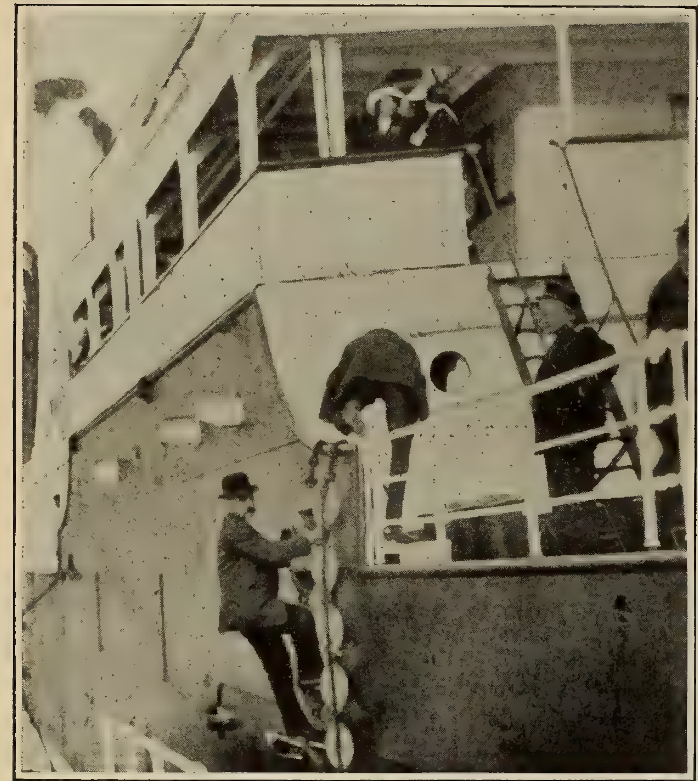
INSPECTING CARGOES FROM THE ORIENT

No imported plant product is immune from inspection. They must be carefully looked over, and undergo quarantine before they land. Every vessel from the tropics and outside of Continental United States as well as those of the states of the Union are subjected to the strictest scrutiny on the part of the legal inspectors.

All botanical immigrants attempting to cross its boundaries must be found "physically" fit to live in the state. Citrus, deciduous and semi-tropical fruits as well as ornamental trees and shrubs, rice, cotton and cereals, vines, dates and melons, which are susceptible to the attack of many insect pests and plant diseases are not released until they have been found free from all the plant maladies. Every person or corporation which brings into the state plant products of any type must notify the plant officer of their arrival and hold the same for their inspection.

The attention of plant inspectors in other countries is called to the insect pests and diseases found on the ship-

ments of plants their countrymen are exporting with the request that a clean up be instituted at the point of origin. Under the new postal law, insect pests of orchard trees found in the parcel post are delivered to the horticultural quarantine inspectors for examination and if they are declared infested beyond treatment they are sent to the State horticultural guardian of Orange County for determination of the *Aleyrodes* infesting its foliage and for final destruction. The inspectors are ever on the alert for the white flies, which infest the cirtus trees. The Federal Government maintains a rigid control over all imports of unmanufactured cotton in the United States as a means of preventing the establishment of the pink boll worm in the cotton fields. At the port of San Francisco, the State quarantine inspectors as agents of the United States



HORTICULTURAL QUARANTINE INSPECTORS BOARDING A VESSEL

Department of Agriculture supervise and enforce disinfection of all imports arriving on the Pacific Coast from points outside of Continental United States.

The fumigation of the cotton is done in a retort. This cylinder holds 75 bales of cotton at a charge, and when filled with cotton a vacuum is created, hydrocyanic gas is admitted into the chamber and the cotton is held in the gas for an hour and twenty minutes. All imported cotton is subjected to the same treatment. Under the law, the inspectors remove and destroy all cotton and cotton lint found in the baggage and personal belongings of passengers arriving from foreign or island American ports. Cotton seed and cotton seed hulls from foreign countries are prohibited from entry under these same regulations. Every precaution is taken to thwart the introduction and establishment of the Mexican boll weevil into California and the quarantine rules covering the bringing in of cotton seed from any other state of the Union have been issued by the State Commission of Horticulture and are rigidly enforced at all times. Cotton seed from any state in which the weevil is known to exist is denied admittance and a permit must be obtained to bring it into the port for experimental propagation. The cotton seed must come from the states that are at present immune from the boll weevil. Railroad cars carrying cotton in the cotton growing states are covered by the quarantine regulations and must be cleaned of all cotton seed immediately upon arrival in California. The railroad companies comply with these rules. When necessary the cars are disinfected with live steam until all cotton in the crevices of the sides and floor is cooked to a soft condition, while in other instances such as "reefers" where the sides are ceiled smooth, the cars are swept and the cotton seed burned. An average of 200 cars, around the bay region of San Francisco, are treated by these methods, inspected, passed and recorded each month.

A vigilant watch is kept for the fruit flies in the passengers' baggage, wherein may lurk the larvae of the pestiferous Mediterranean fruit fly, which is a universal feeder on all fresh fruit and vegetables. The inspectors had a severe experience when they discovered the Mediterranean flies' larvae in seeds of the Kamani tree found in the pocket of an overcoat belonging to a passenger arriving in San Francisco from Honolulu. Had it not been for the keenness of the officer, the seed would have been planted in southern California. No domestic vessel from Hawaiian ports is permitted to land its passengers until a thorough examination is made. They are searched for contraband fruit and plant products in their personal belongings, which task is a rather delicate duty for the quarantine officials.

There are three forms of fruit flies of the Mediterranean species at work on the fruits of the Island of Sydney, one of which is the *Dacus melanotum*, which attacks the alligator

SEARCHING THE BAGGAGE OF PASSENGERS FROM THE ORIENT

pear. Fruits from Papeete on the island of Tahiti are not allowed to land on vessels excepting that which is set forth in the ship's manifest, which consists of a sworn statement of the port at which it was taken on board. The Mediterranean flies thrive in various latitudes not necessarily confined to the tropics. Fortunately it has not been established in California or in any other part of the United States.

Even the vegetable lockers on board the big liners are searched for fruits left over from the ship's supplies. Every food product that is susceptible to the fruit fly is quarantined, as are also the remnants of tropical fruits and vegetables in the ship's lockers and state-rooms.

The future of every crop produced in California depends upon the quarantine service to a large extent. A campaign is

waged against the alfalfa weevil and the white fly, which is a parasite of the fields. From Mazatlan, Mexico, come the dangerous orange maggots, which are a great menace and are known at sight by the inspectors.

Out of 58 counties in California, 42 have county horticultural commissioners or state quarantine guardians. In mountainous counties, where horticulture is not generally prevalent and where horticultural imports from outside of the state are received in a minor quantity, there is less need for the guardians. Coast ports are more susceptible to receiving fruit and melon flies.

An educational feature of the quarantine work is the entomological and pathological system by which records are kept with regard to the findings of the various pests that are discovered on the imported plant products. The clerical records and reports of the service are maintained, collated and tabulated, while the insects are charted and made instantly available for reference in connection with prospective imports of plant production. This is done so that homeward bound passengers, while enroute, may learn what plants are objectionable.

SWEET POTATOES FROM HAWAII INFECTED WITH THE WEEVIL

RESISTANCE OF GREENHEART TO VARIOUS MARINE BORERS.

To what extent greenheart timber resists attack by various kinds of marine borers is being ascertained in a test conducted by the Forest Products Laboratory, Madison, Wis. Six years ago the laboratory placed specimens of this wood in the Gulf of Mexico, in waters infested with holas, xylotrya, and limnoria.

A recent examination of the timbers showed that, except for a very slight trace of limnoria on the sapwood of one specimen, they had been uninjured by either xylotrya or limnoria, although these borers are very active in this vicinity. All the timbers, however, were severely attacked by pholas. The surfaces of each specimen were covered with burrows from ¾ to ½ inch deep.

How far these burrows will extend with continued exposure remains to be seen, but it is not expected that they will extend much more than two inches. Pholas have not been found to bore very deep in wood. It is evident, however, that greenheart piles for use in pholas-infested waters should be made large enough to allow for reduction in size by pholas attack.

Elements of Combustion of Fuel Oil*

From the Report of the United States Naval Liquid Fuel Board

While the theory of combustion is well understood by all having a knowledge of the elementary principles of chemistry, there are particular considerations that enter into the matter of burning both oil and coal as a fuel, and therefore the economical consumption of fuel in large quantities can be effected only in boiler or furnace installations which have been designed by technically trained experts possessing a knowledge of what well may be termed the practical mechanics of combustion.

Hundreds of oil burners have been designed, which, viewed from a mechanical or theoretical standpoint, should have operated efficiently; and yet when such appliances were subjected to actual test the devices proved unsatisfactory. There are, therefore, practical conditions as well as chemical principles that must be considered in the solution of the liquid-fuel problem, and the Board thus regards the mechanical feature of the oil-fuel combustion question as a subject deserving special study and investigation.

Everyone is aware that with a charcoal or coke fire it is possible to maintain intense combustion within a comparatively small space, and with little smoke. This sort of fire was known to the smelters of the Bronze Age, and it is still used in blast furnaces and other operations where great concentration is required.

The explanation lies in the fact that the fuel is solid, even at the highest temperature. The solid particles in the smoke are probably particles of ash, but whether they are ash or unconsumed carbon, they are exceedingly small, as shown by the bright-blue color of the smoke. As a result of this solidity no carbon can leave the bed of hot coals except as a constituent of CO or CO_2. In either case the combustion will be free of soot or smoke, since both gases are colorless and transparent. If the carbon goes up the stack as a constituent of CO, it carries with it two-thirds of the heat that it is primarily capable of yielding up, and it is only with respect to the possible formation of CO instead of CO_2 that a charcoal fire fails to give perfect results. Were it not for this possibility there would be no reason why a charcoal fire should need more space than is sufficient to contain the fuel itself.

The obvious way to prevent the formation of CO_2 is to force a larger quantity of air through the bed of coal, but this alone is insufficient. Experience shows that even when the amount of oxygen passing through the bed of coal is twice that requisite for the complete combustion of carbon, there is still some of the carbon that leaves the furnace in a partly burned condition. The only way in which this carbon can be completely burned is by subsequent diffusion of the gases, whereby each molecule of CO sooner or later meets with an atom of free oxygen and so becomes CO_2. But this diffusion requires time, and as the gases are being constantly cooled as they are carried along it may happen that they will be cooled below the ignition temperature before union takes place So that even in a charcoal fire the need for appreciable combustion space is obvious.

THOROUGH MIXTURE ESSENTIAL TO GOOD COMBUSTION.

Complete combustion requires that for every atom of carbon, and for every two atoms of hydrogen, there shall be at least one atom of oxygen brought in close proximity, and then and there subjected to a temperature sufficient for ignition. In other words, there must be a thorough mixture, and then

*Reprinted from *Power*, March 2, 1920.

ignition. It is doubtful if a mere mechanical mixture, however complete, could ever be perfect enough to bring about the desired result. This is well illustrated by contrasting the smoky combustion of black gunpowder, where there is a mechanical mixture, with the combustion of the so-called smokeless powders in which the mixture is so thorough and minute that similar proportions of oxygen, carbon and hydrogen occur in each separate molecule.

In all ordinary cases of combustion, however, where we draw our supply of oxygen from the atmosphere, it is only by virtue of the property of diffusion that a sufficiently intimate mixture is attained. As to the real nature of diffusion, it is known that at ordinary temperatures the particles of oxygen in the air are moving in every conceivable direction with velocities averaging over 1600 feet per second. Any one atom, however, moves only an inappreciable distance before being arrested by collision with another atom, so that although the average velocity of the atoms is probably equal to that of a rifle ball, it still takes an appreciable time for a particle to travel even a moderate distance. It is this time element that constitutes the great stumbling block when the attempt is made to burn a large amount of combustible in a small space.

COMBUSTION OF HYDRO-CARBONS.

As before noted, the reason why intense combustion is easily attained with a charcoal fire is that the fuel is solid at the temperature of ignition. Being solid it can present a large surface for the oxygen to act upon, and an atom cannot break away and go up the chimney first without being united with at least one atom of oxygen. In the combustion of hydro-carbons, on the other hand, we have the following condition: The fuel is already on its way to the chimney before it is even partly burned. The first effect of the heat is to dissociate the carbon from the hydrogen. Whether or not the latter unites with the oxygen does not affect the soot or smoke question, since the constituents, and also the products of combustion of hydrogen, are like transparent colorless gases. But in any case the carbon left alone in the form of an impalpable dust is much less favorably circumstanced than that in a charcoal fire. If it were attached to a hot coal, as in the charcoal fire, so as to be capable of receiving a blast of air, its combustion would be easily accomplished. But instead of this it is carried along by the current of gases, and unless it is given plenty of time before being cooled it will be left alone as a particle of soot.

An examination of the nature of flaming leads to similar conclusions. The luminous part of a flame is caused by the white-hot particles of carbon. These particles have been robbed of the hydrogen with which they were formerly associated, and they have not yet met the oxygen necessary for complete combustion. This process of finding, or of being found by, the oxygen requires time, and if perchance the temperature falls below that of ignition before the process is completed, the carbon will be deposited as soot or else go on up the stack as smoke along with the excess oxygen, with which it should have been united. Thus an unmistakable symbol of the conditions that are necessary to burn a large amount of combustible in a small space is a short flame. The circumstances which conduce to shortness of flame are: First, pure carbon fuel, because the fuel cannot leave the grate or furnace until it is burned to CO at least. In any case it cannot deposit soot, since CO, when cooled, is a transparent gas. Second, intimate initial mixture of oxyyen with the fuel, since the more intimate the mechanical mixture the less time will it take the gases, by the process of diffusion, to become perfectly mixed. Third, initial heating of the air, since the rate of diffusion increases with temperature. Fourth, large surface of fuel presented for impact of the oxygen.

PROPER SIZE OF COMBUSTION SPACE.

The desirability of supplying a combustion chamber whose volume is at least equal to the volume of the flame seems obvious. In this connection the fact should not be overlooked that a slight increase in the volume of the combustion space acts two ways to improve the solidity of combustion. One way —that having to do with the greater time permitted for diffusion—has already been touched upon; but apart from that there are influences that work, in consequence of which an increase in the volume of the combustion space actually diminishes the volume of the flame. This is because the temperature of the larger space is higher, and the higher temperature hastens the process of diffusion.

During the process of diffusion heat is being liberated at all points throughout the combustion space. Therefore, all parts of the space are being traversed by heat rays emanating from every other part of the combustion chamber. It is readily seen that the temperature within the space must under these conditions increase with the volume to an extent limited only by the transparency to radiant heat, and by the temperature of dissociation at which necessarily heat ceases to be liberated. Since the transparency of the combustion space is diminished by the presence of solid carbon (for whether black or incandescent, it is in any case opaque), it follows that the increase of temperature with a given increase of volume will be less in a space filled with luminous flame than in one filled with burning hydrogen or CO.

INCANDESCENT WALLS HASTEN DIFFUSION.

The question of the proper size of the combustion space is further complicated by the presence and condition of the solid walls of the furnace; whether, for instance, they are themselves incandescent, or merely black absorbers of heat. There seems no reasonable doubt, however, that incandescent walls will hasten diffusion and hence shorten flame.

Where it is possible for the diffusion to be completed before combustion begins as in the bunsen gas burner, the difficulties naturally disappear, and there is readily attained a very short flame, which, moreover, is incapable of depositing soot, even on a cold body.

In the case of liquid fuel, which is incapable of vaporization, the diffusion and ignition must occur simultaneously. With such a fuel there is bound to be considerable flaming. Another difficulty, and one from which all solid fuels are free, arises from this sort of fuel from the action of capillary or surface tension. Thus no matter how finely the liquid is pulverized, each tiny drop assumes a spherical shape and presents the least possible surface for impact of oxygen atoms.

From what has been said it is clear that a liquid fuel, such as crude petroleum, requires an ample combustion space—more, indeed, than does almost any other sort of combustible material.

The relative dimensions, like breadth and depth, of the combustion space are of minor importance. A primary requisite is volume, and that alone provided all parts of it are traversed by the same quantity of gas in a given time—in other words, provided the gases are not short-circuited through or across some parts of the space to the neglect of others. The advantages are in favor of the combustion space of large cross-section and short in the direction of the flow of the gases.

A primary requisite for the successful burning of a non-volatile liquid fuel is the exposure of the fuel to the heat of the furnace in such a form that it presents the largest possible surface for the impact of the atoms of oxygen. From the principles of capillary action it is possible to establish a standard by which to judge of the efficiency of the various methods of increasing the free surfaces of the oil.

Oil in bulk has practically no surface. When broken up into fine drops, the surface is the aggregate surface of all of the drops. The smaller the drops the more perfect the spheres. Hence, drops of oil one-thousandth of an inch in diameter are known to assume the spherical form with a rigidity comparable to that of a steel ball one inch in diameter. The work necessarily performed by the atomizing agent is simply the work of stretching the surface.

FIG. 1. PUFFER FISH DISTENDED WITH WATER

FIG. 2. A DRIED PUFFER LANTERN

Puffer Fishes*

Some Interesting Uses of Their Skins

By E. W. Gudger, American Museum of Natural History

THE puffers are fishes inhabiting tropical and warm temperate seas, and sometimes drifting beyond these limits in warm currents. The Gulf Stream, for instance, carries them as far north as Woods Hole, Massachusetts, while along the North Carolina coast they are very abundant; the writer not infrequently taking a dozen at one haul of the seine in the harbor of Beaufort.

The puffers are short-bodied fishes devoid of scale, or rather having these transformed into spines strong or weak, and are especially notable for having the skin over the belly loose and very distensible. The fish by inflating the abdomen with air or water may more than double its volume, and become a veritable balloon, whence the names puffer, globe-fish, balloon fish. When thus inflated the fish becomes more or less globular in shape with the fins and tail forming mere protrusions. If filled with air, the fishes float at the surface belly up like so many small balloons, for poor swimmers at the best, they are now entirely at the mercy of the wind and tide, having practically no power of locomotion whatever. I have taken scores, almost hundreds of puffers at Beaufort in the seine, and in the great majority of cases they came ashore more or less inflated. If filled with air the fisher boys are sometimes cruel enough to jump on them to hear them explode.

*Reprinted from the *N. Y. Zoölogical Society Bulletin* (New York).

The puffers may readily be caused to inflate their abdomens by fear, by driving them against some obstacle like the net, and especially by scratching them on the belly. I have often taken advantage of this latter characteristic to cause them to swell up, in order to display them to visitors in the aquarium of the United States Bureau of Fisheries laboratory at Beaufort, North Carolina. The air or water is taken into the stomach or into a sac lying in the body cavity external to the stomach, the opening into this being in the throat. This opening has a valve-like structure which readily admits air or water but refuses exit unless at the will of the fish. Air or water is swallowed in a gulping fashion, the abdomen becoming more and more tense like a football bladder attached to a pump or being blown up by a strong-lunged boy. When the water is allowed to escape it comes in intermittent spurts at first, later in a stream, and finally this declines to a mere trickle.

In this connection reference may be made to an interesting modification of this habit in the common swell-toad of our southern coast, *Chilomycterus spinosus*. Dr. Townsend,[1] Director of the New York Aquarium, has noted that this fish in the exhibition tanks there, will sometimes come to the surface and sticking out its mouth will squirt a small stream of

[1]Townsend, C. H. Water-throwing Habit of Fishes in the New York Aquarium, *Bull. N. Y. Zoöl. Soc.*, April, 1909, p. 488.

FIG. 3. BUR-FISH, CHILOMYCTERUS SPINOSUS

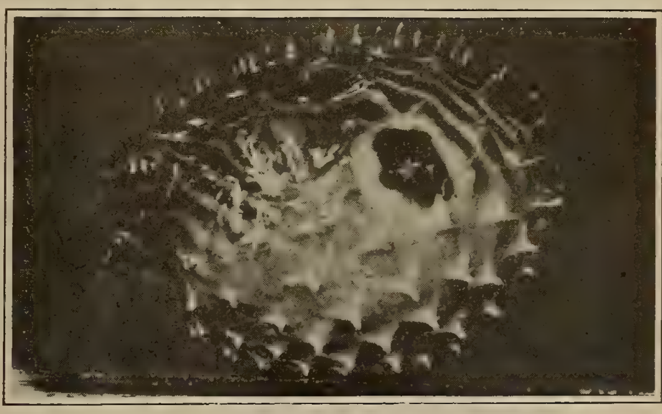


FIG. 4. BUR-FISH FULLY DISTENDED

water into the air. This habit, however, was noted for *Diodon* by Arthur Adams so long ago as 1848.[2]

The trick of inflation is a great means of protection to the puffers. An enemy fish would certainly be greatly astonished and even disconcerted to have a puffer in a few moments swell up to twice its size. Moreover, the rotund shape of the distended fish is a protection against its enemies, since only a fish of extraordinary gape can take one in whole; the ordinary fish in biting at a puffer merely pushes it away or causes it to roll over. Further these fishes, especially the ones called porcupine fishes, are covered with spines, *Diodon hystrix*, with its long, slender, needle-pointed spines, being the best example. If the puffers with few and weak spines are well protected by their ability to inflate themselves how much more are those like *Diodon*, which when inflated are covered hedge-hog-like with an almost impenetrable forest of fine pointed spines.

Some of the puffers grow to be three feet long, but these are the giants of the tribe. The largest ever seen by the writer was about two feet long, and the smallest about the size of a forty-four-caliber bullet, or the size of the end of one's little finger. This was a little *Chilomycterus antillarum*, as its name indicates, a straggler from the far south, taken by the writer in a tide-pool, on a sandbar in the mouth of Beaufort

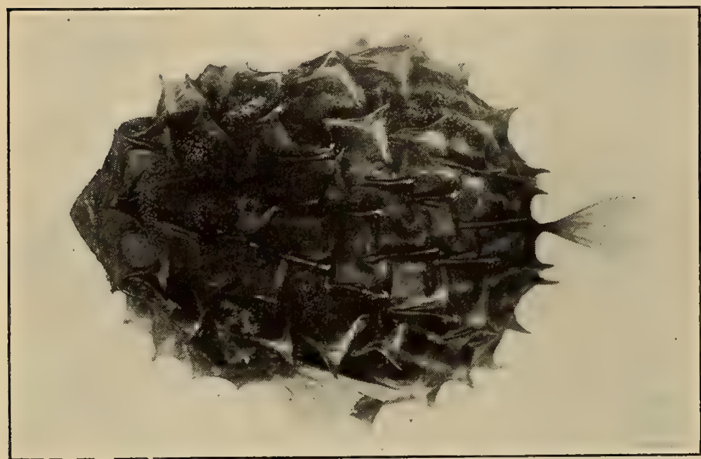


FIG. 5. DRIED BUR-FISH
Photographed from above by the author

Harbor. It was an interesting little fiesh, and, as it was kept in an aquarium for some time, it became a pet. It fed greedily on bits of oyster and I used, when it was trying to swallow a fragment of oyster, to take it in my hand and tickle it on the belly whereupon it would partly inflate its abdomen. Then when freed in the aquarium it would set its tiny fins and sculling with its diminutive tail would make its way to the bottom. However, its small specific gravity would not let it remain there, and like a true balloon it would come to the surface only to begin the struggle again, and this would continue until the oyster was swallowed so that the air could be discharged.

The puffers belong to that suborder of fishes known as Gymnodontes, naked-toothed fishes, so called because the lips are drawn away from the teeth whihch in turn are solidly fused into beak-like masses. The puffers considered in this paper belong to two of the four families which comprise the *Gymnodontes*. The first family is that of the puffers proper, the Tetraodontidæ, so called because each beak is divided by a suture in the median line into two halves, making four parts to the jaws; *tetra*, four; *dens*, tooth: four-toothed. These fish have an inflatable sac lying outside the peritoneum with an opening in the esophagus. The other family is that of the porcupine or globe-fishes, the Diodontidæ, which have

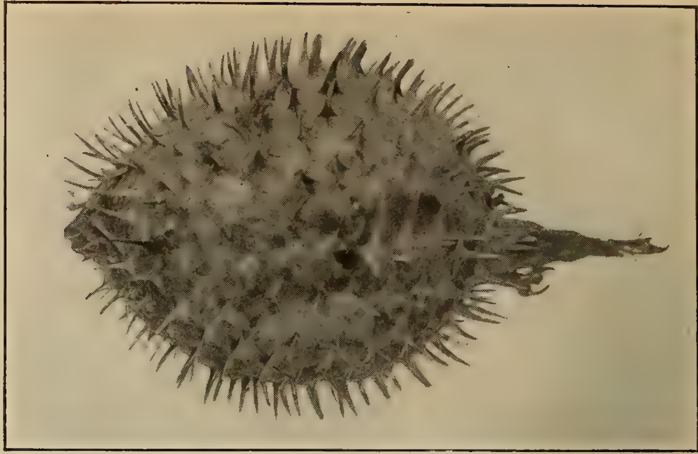


FIG. 6. GLOBE FISH, LATERAL VIEW
Photographed by the author

no suture or fissure, and hence are Diodontids (*di*, two; *dens*, tooth) two-toothed. These inflate the abdomen by taking air or water into the stomach, its exit being controlled by sphincter muscles in the gullet.

The common puffer, swell-fish, or swell-toad of our Atlantic Coast is the Tetraodont *Spheroides maculatus* whose name describes its appearance quite accurately. It is taken so frequently in the seine at Beaufort that it is not even regarded as a curiosity. Fig. 1 is a side view of this fish showing how it distends itself with water.

Another Tetraodont puffer found on the North Carolina coast, is the so-called rabbit-fish, *Lagocephalus laevigatus*. While not common at Beaufort, the fish is occasionally taken in haul-seines, and in the course of ten summers' work at the Bureau of Fisheries laboratory there the writer has seen some half dozen specimens. The fish justifies its name—*laevigatus*, smoothed; *Lagocephalus*, hare-head—inasmuch as the head and mouth somewhat resemble those of a rabbit, and the skin is smooth and entirely devoid of prickles.

The porcupine-fishes and the bur-fishes belong to the second family referred to above, the Diodontidæ, and are fishes having all the tooth structures in each jaw confluent into a turtle-like beak. In addition to their peculiar tooth structures these fish have the scales converted into spines or prickles. Two genera of this family are found on our Atlantic coast, *Diodon* and *Chilomycterus*, and both are reported from Beaufort, the former from one specimen only and the latter from hundreds.

Chilomycterus spinosus, the spiny toad-fish, is the most common puffer on the North Carolina coast. Caught by dozens in the seine, our aquarium in the Beaufort laboratory

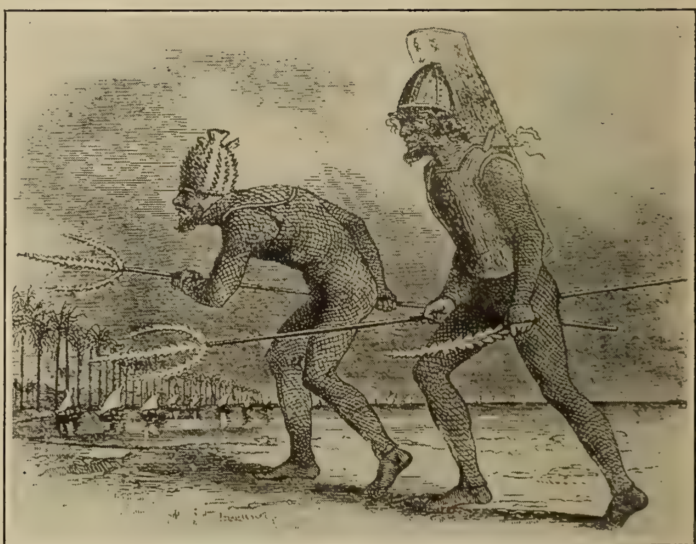


FIG. 7. DIODON SKIN HELMET—DRUMMOND ISLANDER (KINGSMILLS). AFTER WILKES

[2]Adams, Arthur. Notes on the Natural History of the Islands (of the East Indies) in Sir Edward Belcher, Narrative of the Voyage of H. M. S. Samarang in the years, 1843-46, Employed in Surveying the Islands of the Eastern Archipelago. Vol. II, 1848.

FIG. 8. A TARI TARI ISLANDER, GILBERT GROUP, WEARING A DIODON SKIN HELMET. AFTER MAYOR

FIG. 9. MARSHALL ISLAND NATIVE WEARING A DIODON SKIN HELMET. AFTER ALEXANDER

FIG. 10. GILBERT ISLAND WARRIOR WEARING A DIODON SKIN HELMET. AFTER HARTZER

was rarely without one or more specimens. However, it was necessary to watch it in one of the large tanks in the New York Aquarium to see a feat next in interest to its habit of inflation. Here one day Dr. Townsend pointed out its habit of getting in the current of the incoming jet of water and turning somersaults. Fig. 3 shows the specimen *au naturel* while Fig. 4 is from a photograph of an inflated specimen.

Both these figures[3] are from photographs of a living fish, while Fig. 5 is a dorsal view of a dried specimen in the author's possession. The spines on this puffer, as all the figures show, are short and blunt and not very offensive.

The most interesting of all the puffer-fishes is the porcupine or globe fish, *Diodon hystrix* (*hystrix*, the porcupine or hedgehog). This fish is a tropical form, common to all the warm oceans of the world, but on our coast is not normally found north of Florida. As a straggler the Gulf Stream sometimes carries it as far north as Woods Hole, Massachusetts. At Beaufort but one specimen has ever been taken, and that curiously enough was a young specimen only two and five-tenths inches long. The fish is not uncommon in southern Florida, and in the curio shops at Key West there may be seen elegant specimens of the fully distended dried fish, some fifteen inches in length. During several summers spent at the Tortugas laboratory of the Carnegie Institution of Washington, I was constantly on the lookout for the porcupine-fish, but vainly so. However, Prof. W. H. Longley one day had the good fortune to see two fine specimens drift by the eastern dock, but tantalizingly just out of reach of his longest dip net. They were fully inflated and were rapidly carried out to sea by the tidal current setting in that direction. As all the boats were on the other side of the island, half a mile away, pursuit was out of the question. Fig. 6 is a lateral view of a dried specimen in full inflation.[4] This figure shows well the justification of the names, porcupine-fish and globe-fish.

These fish, when put alive into preserving fluids like formalin or alcohol, will sometimes die inflated, and may then be dried. I have found it better to dilate the stomach or extraperitoneal sac with strong formalin pumped in with a syringe, and then to hang the fish up until it is both dry and cured. Such fish are quite translucent and Dr. Townsend has in the New York Aquarium such a fish, an Hawaiian species, converted into a lantern, the fish being hung up with a candle or small electric light suspended inside. Fig. 2 is reproduced from a photograph of this puffer-fish lantern and is taken from Dr. Townsend's article on "The Puffer, Its Defense by Inflation," published in the *Bulletin* of the New York Zöological Society for March, 1916, page 1331.

In this article Dr. Townsend further says:

"It is a common practice with the Japanese to make lanterns of inflated and dried puffers by cutting out the back as shown in the accompanying photograph of a puffer 'lantern' in the New York Aquarium. A candle suspended by a wire serves as a light which shows as brightly through the stretched skin of the fish as through a piece of oiled paper." The puffer from which this lantern is made is eighteen inches long. In the course of a fairly extensive examination of books of travel in the South Seas, a number of instances of a still more remarkable use of the skin of the porcupine fish *Diodon* has come to hand. If this fish makes use of its spine-covered skin for its own protection, why should not man likewise and for the same reason use it? And so the ingenious natives of these interesting regions have done. Commander Charles Wilkes, in Vol. V of his Narrative of the United States Exploring Expedition during the years 1838-1842 published in 1845, has on page forty-eight a figure of a Drummond Islander wearing a helmet made of the dried skin of a porcupine fish, *Diodon*. There is, however, no reference to it in the text. The figure is reproduced herein as Fig. 7. Wilkes also gives a separate drawing of the helmet.

A few years later (1847), however, we come across a very definite statement in John Coulter's Adventures on the West Coast of South America and . . . Including a Narrative of Incidents at the Kingsmill Islands, etc. In Vol. I, page 191, he describes the Drummond Islanders (in the Kingsmills) accoutered for war, the head being "surmounted by an extraordinary looking apology for a helmet, in a conical shape and made of dried fishes' skin, with two or three feathers of various colors stuck in the top for a plume." In the next few pages he twice refers again to this "fish-skin cap."

Likewise George French Angus, in his book Polynesia (London, 1866), says of the Kingsmill warriors that: "On

[3]These photographs were made in the Fisheries Laboratory at Beaufort by a professional photographer whose name cannot be recalled.

[4]This dried specimen was very kindly loaned me for photographic purposes by Mr. E. E. Hanner of Greensboro, N. C.

the head is worn a cap formed of the skin of the porcupine fish, bristling with sharp spines."

The next account chanced upon is from the pen of William Wyatt Gill, a missionary in the South Seas whose powers of observation were keen and highly developed as the wealth of natural history notes in his books shows. On page 108 of his Jottings from the Pacific (New York, 1885), he writes that "The Islanders came to see the white strangers and to dispose of helmets of porcupine fish (skin)."

Chronologically we next come in 1890 to James Edge-Partington and Charles Heape who published at Manchester, England, in two volumes their very interesting Album of the Weapons, Tools, Ornaments, and Articles of Dress of the Natives of the Pacific Islands. In Vol. II, page 170, is a figure of a native of the Kingsmill Group wearing a cap of fish skin. There is no descriptive text and as the figure is not very distinct, it will not be reproduced here.

Our next authority is James M. Alexander, whose book The Islands of the Pacific was published in 1895. To face page 222 is a plate, the lower half of which, shows a Micronesian wearing a dried *Diodon* helmet. Comparison with Wilke's figure shows that Alexander has copied it without giving any credit whatever. To face page 230 is another plate the lower half of which is labelled "Marshall Island Warrior." This man also wears a *Diodon* helmet. This figure is given as number 9 of the present paper.

Our next reference is to a book[5] by Ferdinand Hartzer, a Catholic missionary in the South Seas. Under date of 1900, he writes that the Gilbert Islanders go into battle variously armed while "A casque, fashioned out of the dried skin of a large fish with strong spiny scales surmounts the head as a helmet." On this same page is a pen and ink sketch showing this helmet and to face page 248 is a photograph of a native in full armor. This latter figure is reproduced herein as Fig. 10.

Few men of the present day have a wider or more accurate acquaintance with the South Seas and with the customs of the people living therein than Dr. Alfred G. Mayor. In an article, "Men of the Mid-Pacific," in the *Scientific Monthly* for January, 1916, Dr. Mayor has an illustration showing a warrior of Tari Tari Island, Gilbert Islands, armed with weapons beset on the edges with sharks' teeth, and having on his head a helmet of dried *Diodon* skin. Through Dr. Mayor's kindness, this illustration is reproduced as Fig. 8.

Study of the localities noted above shows that the use of dried *Diodon* skins for helmets is confined to the inhabitants of the Kingsmill, Gilbert and Marshall groups; in short to that part of Oceanica known as Micronesia, the region of "little lands," as these islands have been named. The reason for this must be an ethnological one, and in that science the explanation must be found.

[5]Hartzer, Fernand. Les Iles Blanches (Archipels Gilbert et Ellice) das Mers du Sud. Paris, 1900.

Milk and Petroleum*

Loss of Efficiency in Lubricants Due to Refining

By Edward G. Acheson, Sc. D.

THERE is a striking similarity in the physical make-up and composition of milk and petroleum and this likeness is carried throughout the natural and artificial treatments they are subjected to.

In milk the major part is just plain simple water in which are millions of minute particles floating about. These small particles are invisible to the naked eye, nor can they be seen in the ordinary powerful microscope. It is only by the use of an ultra-microscope that they can be detected, and then they are seen to be in constant vibration even after the milk has been standing at perfect rest for a long time.

The manner in which the ultra-microscope makes it possible to see the minute particles in the milk can be well illustrated by means of a very common and well-known fact. You look across a room or at an object in the room and see with such distinctness that you comment on the perfect clearness of the air. Now darken the room and allow a ray of sunlight to pass through the air and you at once trace the line of the sun's rays by innumerable particles of solid matter floating in what you formerly thought was perfectly transparent air. They have been made visible by the sun's rays when thrown into contrast with the surrounding darkness. So with the ultra-microscope. By means of a ray of arc light minute particles that are invisible under a powerful microscope, are made visible in the same instrument by means of this bright illumination. These minute particles in vibration are termed in scientific language colloids and the vibratory movement was first seen by a man of the name of Brown, and ever since this movement has been known as the Brownian movement.

The fresh milk as taken from the cow is largely or wholly composed of three substances. The greater part is pure, ordinary water. In this water are colloids of two distinct varieties. If a pan of fresh milk be set aside it is only a matter of a few hours until the colloids of one variety collect at the top of the milk where they form our well-known cream. The cream having been skimmed from the milk and set aside will in a short time sour, an acid having been formed in it. This sourness or acidity causes the colloids of the cream to coagulate, or gather together in small globules, which are recognized as fat. The soured cream is next put through a churning process which causes the small globules of fat to unite, forming what we know to be butter, and this when carried to the proper state is removed from the water.

Having disposed of our cream by the removal of the colloids as butter, we will now turn to what we ordinarily term our skim milk, and we find in due time this will also turn sour and the white matter in the milk coagulate, and perhaps you have seen this product poured into a suitably arranged bag and the water drained out, leaving our cottage cheese in the bag. With the removal of the colloids in the form of cottage cheese and the final elimination of the water we have completed the total destruction of the milk and its separation into three products, butter, cheese and water, and the first step in this separation is the formation by Nature of an acid within the liquid, the presence of this acid being quite essential for the removal of the fats, or food material, from the water with which they are associated. An alkali, such as lime or caustic soda, would have accomplished the same result, but Nature uses an acid as the means.

Petroleum as taken from the earth is also full of colloids, but it is not so easy to understand as milk. Its chemical composition is now well known, but there has not been a clear comprehension of its physical make-up, and this notwithstanding the fact that the value of petroleum largely depends on the physical characteristics of its several components which range from the thin, clear benzine, through our kerosene, fuel and lubricating oils. The thickness, or what is termed viscosity, of these several component parts increases in the same order from the benzine to the heavy lubricating oils.

*Reprinted from *Oil News*, Jan. 20, 1920.

An examination of the many products of petroleum, by means of the ultra-microscope, discloses the fact that colloids exist in all of them with the exception of the benzine, and, further that the number of colloids present increases as the petroleum product increases in viscosity, and this, naturally, leads to the idea that the viscosity may be due to the presence of the colloids, but whether that be true is not an assured fact, yet it is a fact that it is to them that lubricating oils owe their greasiness and unctuousness. It is the greasiness of lubricating oils that causes it to adhere to the surfaces of the shaft and bearings, thereby keeping them separated, while its unctuousness causes easy slipping of the surfaces, and as these two qualities are due to the presence of the colloids, it is evident the real value of the lubricating oil lies in these colloids.

As the value of petroleum lubricating oil lies in the colloids present in the oil, and, in turn, the existence of our industrial life depends on lubricating oils, it is well to have a fair understanding of the nature of these all-important ultra-microscopic particles. They have the greasiness and unctuousness of the butter colloids, which are commonly known as fat, hence we cannot be much in error if we call the colloids found in petroleum, fat. One we know as an animal fat, and the other we will call petroleum fat.

It is quite well understood that an animal fat cannot be rubbed off a surface upon which it has been applied, nor will plain water remove it. We use soap and water. Apply such a test as this to a lubricating oil. Take the same oil before and after being subjected to the usual filtering process as carried out by the oil refiners: select four pieces of glass, such for instance, as the common glass slide used in mounting objects for microscopic examination; on the center of one slide place a drop of the unfiltered oil and cover the drop with another one of the slides; on the third slide place a drop of the filtered oil and on this place the fourth slide. Now taking these two sets in your hands between the thumbs and fingers, rub them for some minutes, after which place both hands beneath the surface of water and continue rubbing the two sets of slides under the water the same as they were rubbed in the air. In a few minutes it will be found that the two glass plates between which the filtered oil was placed are in contact, the oil having been washed away by the water, whereas the plates between which the unfiltered oil was placed are not in contact, and upon removing the slides from the water it will be found there is a real grease or fat body between the glass plates, and this cannot be removed, excepting by the use of soap and water. The result of this test can only be construed as proof that the filtering removes valuable fats, the oil being improved in appearance at the expense of its efficiency.

All colloids are subject to much the same laws. Acids, most alkalies and chemicals generally are poison to them, their colloidal state being destroyed, as has been shown in the case of the soured cream and skim milk. Another important point is that they adhere to any object they are brought in contact with. This fact has been commented on as a valuable one in lubrication when they adhere to the surfaces of the shaft and bearing.

Having thus briefly, and in a very general manner, reviewed the characteristics of colloids, and more particularly fat colloids, let us look into the methods usually practiced in the so-called refining of petroleum lubricating oil.

Previous to the discovery of petroleum in quantity, there was sold on the market for illuminating purposes, what was called "coal oil." This coal oil in its use was made to ascend a wick, and to do so successfully it was found necessary to treat it with sulphuric acid in order to free it from impurities that caused clogging of the wick. This same acid treatment was found necessary with kerosene as taken from petroleum. The preparation of kerosene for the market eventually took some such form as this—treatment with strong sulphuric acid followed by a treatment with caustic soda, followed by washing with water, followed by filtration through fullers' earth. It would not be expected that any fat colloids present in the crude kerosene would escape this extended chemical and filtration treatment. Nevertheless, some of them do, as can be seen in an ultra-miscroscope. It is the presence of these few fat colloids in kerosene that causes this liquid to produce a grease spot or stain on any fabric it is brought in contact with. The main purpose of the chemical and filtration treatment of kerosene is to remove the fat colloids.

It may be found difficult to believe that this highly successful method of removing the fat from kerosene would be used in the treatment of lubricating oils, for their worth is wholly due to them, but nevertheless, such is the fact. A number of methods and processes are practised in the treatment of lubricating oils, but each of them contains all or a part of the steps practised with kerosene. In some cases as must as eight per cent in volume of the oil is lost in the treatment with a sulphuric acid and still other amounts are lost in the caustic soda and filtration treatments. At least one-half of the coal consumed in making steam to run manufacturing plants is wholly lost in friction, and as our lubricating oils are used to reduce or prevent friction, any treatment that tends to diminish the lubricating value of the oil should be looked upon with pronounced disfavor.

Undoubtedly the processes through which the oils are passed improve their appearance immensely because the presence of the fat colloids tends to produce a dark and rather unpleasing apparance, and this is quite objectionable from a salesman's point of view. The public, and more particularly the manufacturers, should not be interested in the color of an oil. They should demand of the oil salesman some proof as to the lubricating values of the oils he offers for sale. Evidently the refiners must know their refining processes reduce the efficiency of the oils as lubricants as evidenced by the fact that they use black oil that has not been subjected to a high degree of refining when they themselves undertake extensive lubrication, as in railroad car journals.

The more thoroughly the question of lubrication is studied, the more positive the conviction becomes of the truth of the statement recently made by Mr. W. B. Hardy, F. R. S., secretary of the Royal Society of England, that "the problem of lubrication is merely a special problem of colloidal physics."

CONTRAST SENSIBILITY OF THE EYE.

A knowledge of the contrast sensibility of the eye is very essential to the proper understanding of the theory and use of searchlamps and searchlight illumination.

The searchlamp is used at night when the eye is generally adapted to low levels of illumination. If the observer is far removed from the searchlamp the illumination may be simply that from the moon and sky. If he is near the lamp, however, he must look through the diffused light along the beam.

In order to be visible, the target must be illuminated to a degree that will make sufficient contrast in brightness or color between it and this surrounding field. Data are given showing the relationship that exists between the brightness and the size of the target and the brightness of the surrounding field.

In these experiments a large surface painted white was illuminated with an incandescent lamp. The target consisted of a rectangular spot of this surface more brightly illuminated by means of a projection lantern, equipped with a simple bilateral slit. The image of the slit determined the boundaries of the test spot or "target," the length of which could be varied by varying the slit width. Precautions were taken to have the brightness across the image of the slit uniform. The brightness of either the test spot or field could be varied by means of sectored disks, so that any desired contrast between them could be obtained for any given brightness of field.—Abstract of *Scientific Paper of the Bureau of Standards* No. 366, by Enoch Karrer and E. P. T. Tyndall.

The Synthetic Tannins and Their Use in Tanning*

Efforts to Replace the Natural Vegetable Product

By Ed. Nihoul, D. Sc., Professor of Chemistry at the University of Liège

> *The significant statement was recently made by an important English journal dealing with the leather trade that the great German dyeworks, the Badische Anilin und Soda Fabrik is still taking out patents for further products based upon Stiasny's invention of Neradol, being evidently convinced that there is a dazzling future in store for synthetic tanning material, which will probably prove to be "as big a gold mine as synthetic indigo."*
>
> *They add: "There is in addition a German patent No. 262,558 which appears to cover a very wide range of substances capable of converting animal skins into leather." The French chemical journal, Chimie et Industrie, in commenting upon this statement, remarks that while it is true that the great German chemical works has continued during the last two years to take out new patents upon sulphonated products to be used in tanning it is by no means certain that it is in this direction that the industry of "synthetic" tannins will develop. Without pretending to decide as to the merits of these two views we are of opinion that the subject is one of great importance and interest, both on account of the ominous rise in the cost of leather, for whose various applications no entirely satisfactory substitute has even been found, and because of the steady diminution in the sources of supply of natural tannins. We are, therefore, glad to present to our readers the following discussion of the matter by a distinguished authority.*—Editor.

According to Trimble's classification, the one most generally accepted, the tannins are divided into two groups: the pyrogallic tannins and the catechic tannins.

Pyrogallic Tannins.—These tannins are derived from pyrogallol, and possibly, in the case of some of them, from phloroglucine. This group includes the tannins extracted from the wood of the oak and the chestnut and from the bark of the willow as well as the tannins obtained from the sumac, the valonia, the divi-divi, the algarobilla, and the myrobolans.

All of these tannins behave differently with respect to hides and yield dissimilar results. This is due in large part to other substances combined or associated with the gallotannic acid. Among the former those of special importance are gallic acid, ellagitannic acid, ellagic acid, and other compounds whose molecular formulas are not known and among which several (catellagic, metallagic, and flavellamic acids) differ from ellagic acid only in their oxygen.

The tannin of oakwood is supposed to be a methylic derivative of gallotanic acid mixed with other compounds which readily insolubilize the surface of fibres. The myrobolans, the valonia, the divi-divi, and the algarobilla even contain besides gallatanic acid another compound, ellagitannic acid, which yields a deposit of ellagic acid either through the action of ferments or of mineral acids.

The extracts of oak wood, divi-divi, and algorabilla contain pyrogallic tannins which resemble at once gallotanic acid and ellagitannic acid. Gallic acid is found in the company of most of the pyrogallic tannin, from which it is derived by hydrolysis. Gallic and gallotannic acids are quite well known, while our knowledge of the other two is of more recent date. Ellagic acid is particularly interesting because of its importance in the tanning of heavy leathers. Perkin has demonstrated that it is a double lactone derived from hexa-hydroxy-diphenyl-dicarbonic acid whose composition, as well as that of ellagitannic acid, has been made known by Meunier.[1] I will add that the formula of gallotannic acid as stated in works upon general chemistry and upon the art of tanning has been much discussed because of the fact that this acid, which is obtained by synthesis, is not optically active, while tannic acid, which is obtained from natural pyrogallic tannin, affects, on the contrary, polarized light. . . . Nierenstein regards tannin as very different from ellagic acid from the fact that the first when distilled with zinc powder gives diphenyl—methane $C_6H_5\ CH_2\ C_6H_5$ while in the same conditions the second gives fluorene $\begin{matrix} C_6H_4 \\ | \\ C_6H_4 \end{matrix}\!\!>\!CH_2$

By acetylizing tannin we obtain two different products, one of which pent-acetylate, melts at 203° C., while the other, hexacetylate melts at 116°C. He believes tannin to be composed of a mixture of gallotannic acid which yields pent-acetylate and its reduction product, the leuco-derivative, which yields hexo-acetylate, and that it is this leuco-tannin which causes the activity of the natural product.

Catechic tannins.—These are derived from pyro-catechin, and some of them, perhaps, from phloro-glucine; they are sometimes found mixed with pyrogallic tannins in natural products. To these are added the extracts from the bark of the oak, beech, pine, hemlock, mimosa, and mangrove, as well as the tannin from the quebracho, the gambier, the cachetu, etc. These also behave differently with respect to the hides, varying even more perhaps since they are associated with a larger number of foreign substances; among these we may especially mention:

a. The catechins, the hydrolytic products of these tannins. These are slightly soluble in cold water. Perkins has isolated and studied the catechic tannin of the gambier, which he obtained crystallized with four molecules of water, its formula being $C_{15}H_{14}D_6 4H_2O$;

b. The phlobaphenes, which are the products of condensation, on the contrary, and which proceed from the de-hydration accompanied by oxidation of the catechic tannins. Each tannin posesses a series of these anhydrides, and the further dehydration is carried the less soluble and the more highly colored they are.

Among the catechic acids the most important include (1) the quercitannic acid of oak bark, which forms derivatives with bromium and fixes 28.4 per cent of this substance; this acid is also found in the bark of the mimosa.

(2) Quebracho-tannic acid, which fixes 43 per cent of bromium.

(3) Cachou-tannic acid, which fixes 50 per cent of bromium.

Finally, there may be mentioned among the tanning substances found in this group coloring products having a constitution which is quite complex; these are called flavones.

None of these catechic tannins has been isolated in the crystalline state and pure, and no one has any exact idea as to their structural formulas. All one can say is that they have excessively high molecular weights. Koerner found the molecular weight of the tannin of the quebracho to exceed 1,000. According to Paterno, these weights may vary between 2,500 and 3,500. It results from this that the tannins exist in water in the form of a colloidal solution. They are much better absorbed by the hydrogels when they are in the form of an aqueous solution than when dissolved in other vehicles. Wislicenus has proved that in certain conditions tannin is absorbed by nascent alumina in the proportion of 78 per cent, while in an acetic solution the proportion is only 32 per cent. Koerner also found an absorption of 99 per cent for

*Translated for the *Scientific American Monthly* from *Chimie et Industrie*, Paris.

[1] *Chimie et Industrie*, 1918, vol i, No. 1, page 75.

quebracho tannin in an aqueous solution and only 53 per cent in an acetic solution.

Prof. Procter, who has studied the phenomena of tanning quantitatively, has shown that the difference of potential which exists between the superficial layer of the micellary particles of tannin and the mass of the solution, diminishes in proportion as the concentration of the electrolyte augments. When this difference becomes very small the tannin begins to become flocculent and since the micellae of gelatine and of the skin substance have precisely opposite signs this authority believes that it is the electric neutralization of the particles in contact which produces the co-precipitation of the two colloids, thus causing the fixation of the tannin upon the skin, and also the absolute insolubilization of the fibre thus transformed, which appears to be due to phenomena of a different kind.

As a matter of fact it has been thoroughly demonstrated that the vegetable tannins are colloids, and this being true it is believed that there can be no question of obtaining by synthesis compounds which are *identical* with the natural tannins.

RECENT SYNTHETIC STUDIES IN THE GROUP OF TANNINS AND THE PROBABLE ACTUAL CONSTITUTION OF PYROGALLIC TANNINS.

The formula of digallic acid has long been attributed to the tannin obtained from gall-nuts. Walden observed in 1897, that the natural product differs from tannin acid by several of its physical properties, in particular by its electric conductibility and by its behavior with respect to light. Moreover, arsenic acid exerts a different action upon the two products, and the molecular weight of tannin is manifestly higher.

Nierenstein suggested that natural tannin might be a mixture of digallic acid and its optically active reduction product. leuco-tannin. But such a mixture ought to be more acid than the natural product and ought to have apparently a lower molecular weight.

Fischer has made progress in the study of this question, as shown in his various works published between 1906 and 1913. He began by purifying the natural product obtained from Chinese gall-nuts, by eliminating the compound containing free carboxyl groups by means of ethyl acetate; in this manner he obtained an optically active product. He next studied the products of hydrolysis obtained by the acid method. He found that pure tannin decomposes into one molecule of glucose and ten molecules of gallic acid. This would indicate that the natural substance is an ether compound composed of five molecules of digalic acid and one molecule of glucose.

Fischer attempted the synthesis of the corresponding gallic compound. The operation was not possible by means of the ordinary process, proceeding by means of the chloride of the acid since the clorine of the cloride of phosphorus bears the same relation to the phenolated OH groups. He began by fixing the OH groups of gallic acid by the chloride of acetyl.

The carbo-methoxy derivative thus obtained by the elimination of hydrochloric acid is sufficiently stable to permit the reaction of the chlorine upon the carboxyl group. It should be easy consequently to reconstitute the hydroxyl group by expelling the carbo-methoxyl groups by means of slow hydrolysis. He, therefore, caused the chloride of the acid to react upon the glucose in a chloroformic solution by employing quinolein to fix the hydrochloric acid form, which gave him the penta-tricarbo-methoxy-gallate of glucose. . . .

The compound thus obtained was saponified by a slight excess of alkali dissolved in an aqueous solution of acetone. under these conditions the carbo-methoxyl groups are removed at ordinary temperatures and the penta-gallate of glucose is isolated. This compound is very similar to tannin, different from it, however, by the fact that it exerts no action upon light.

Herzig undertook the synthesis of methylo-tannin and obtained by hydrolysis tri-methyl-galic acid on the one hand, and on the other the a-symmetrical m-p-dime-thyl-gallic acid.

These facts cause us to suppose that tannin is an ether of glucose with five molecules of m-digalic acid. However, it is possible that these compounds which enter into combination with the digallic acid are poly-saccharids, and that the glucose is produced only by the hydrolysis of these compounds. The different products prepared by the preceding method, by means of various hydroxy-acids and of saccharids, possess characteristics analogous to those of the tannins. However, up to the present time no one has been able to prepare these substances at a price even remotely approximating that of natural tannins. Substitutes alone have been put upon the market.

PRACTICAL DEFINITION OF THE SO-CALLED "SYNTHETIC" TANNINS

The word tanning as used in industry signifies the transformation of hides in which leather, *i. e.* an ensemble of transformation whose object is to render the hide non-putrecible, non-sensitive, or but slightly sensitive, to the action of water and of dilute chemical substances and not rapidly affected by bad weather, etc., while at the same time preserving a certain degree of flexibility (which varies according to the kind of leather), a certain degree of elasticity of the original tissues, and a sufficient amount of resistance to traction, etc.

Substances capable of producing these results are numerous and very varied. They include, in particular, besides the natural tannins, fatty substances, formol, and a large number of mineral substances, especially the salts of cromium, of aluminum, of iron, of zinc, of sulphur, of silicon, etc. In the industrial sense of the word all of these products are tannins. It is not strange, therefore, that investigators have sought in the group of phenolated compounds substances capable of causing the same results.

The first researches along this line were made by Prof. Mennier, of the University of Lyons. The process of tanning by means of quinone, which he perfected, was in use in France and Germany before the war. Prof. Stiasny of the University of Leeds endeavored to prepare by synthesis phenolated compounds of a more complex character, with the object of obtaining compounds more closely resembling the vegetable tannins. He manufactured a substitute which the *Badische Analin und Soda Fabrik* patented under the name of "Neradol D," which was employed in Germany and particularly in England. These two compounds can be obtained simply and easily as by-products and may even occur as residues in the utilization of substances derived from the distillation of coal which the allied countries propose to continue to treat in large quantities after the war. . . .

ACTION OF QUINON UPON GELATINE AND UPON SKINS. MEUNIER'S RESEARCHES.

a. Action Upon Gelatine.—In 1908 Meunier and Seycewitz published their researches concerning the insolubilization of gelatine by the action of the following organic compounds: phenol, resorcine, orcine, hydro-quinone, pyrocatechin, gallotannic acid, pyrogallol, paramino-phenol, chloro-phenol, picric acid, adurol (mono-chlor-hydro-quinone), the beta-naphtol-di-sulphonic acids (R. G. acids), and beta-naphtol-mono-sulphonic acid (S. acid). . . . The phenols, which are only slightly soluble in water, such as the alpha and beta naphtol (not more so than the amines), the amino-phenol, simple or substituted, whether in the state of free bases or in the state of salts, do not yield a precipitate in gelatine solution.

When the precipitation occurs under conditions favorable to oxidation, the phenol and even the amino-phenols yield precipitates which are insoluble in boiling water. The discovery of this fact led investigators to test the products of the oxidation of the phenols. The quinones and particularly ordinary quinone were especially tested in this regard. They found that "quinonated gelatine constitutes the most stable form of insoluble gelatine thus far known," since it resists

not only the action of boiling water but also that of dilute acids and alkalis.

The non-solubilization occurs with extreme rapidity . . . having been obtained even in less than two hours at 15° C. The quin-hydrones act in the same manner, but more slowly. Experiments with formaldehydide, on the contrary, yield a product which dissolves totally in hot water upon repeated treatments and which decomposes under the action of a high heat into formaldehydes. This product is dissolved by a cold hydrochloric acid at 15° C. and by dilute alkalies.

b. Action Upon Skins.—The same results were obtained with the phenols and the amino-phenols in the presence of oxidizers as with the quinone compound employed with oxidizers. Comparative tests of other compounds capable of affecting dermic tissues have led to the conclusion that a quinone solution containing only one part of quinone for every one hundred parts of raw skin will insolubilize the tissue and transform it into leather whose resistance to the action of water, alkalis and acids is superior to that of all other known leathers, including the chrome leather, and whose resistance to friction is, at least, equal to that of the above leathers tanned by oak bark.

The analysis of the baths used has demonstrated the presence of hydro-quinone, which proves that a portion of the quinone has served to oxidize the skin substance, while the rest of it is combined in a stable manner with the oxidized skin. But hydro-quinone is eminently oxidizable and the yield would be better if one could succeed in reoxidizing it. Hence all conditions which favor the absorption of oxygen. likewise favor tanning. The use of catalyzers (laccasses, artificial peroxy-diastases, the acetates of manganese, of cerium, of lanthanium, etc.) will make possible, therefore, a quicker and more perfect utilization of the quinone. Meunier also observed that oxydases which are found among the soluble matters are given up by the skin during the process of tanning.

PROPERTIES OF QUINONE AND METHOD OF OBTAINING.

The quinones in general are obtained by the oxidation of the corresponding para-diphenols. They are also produced when the OH groups number more than two, provided that two of them exist in the para position. They are formed by the oxidation of a large number of compounds derived from the phenols, *e. g.* *p*-phenol-sulphuric acid or other amino-phenolated compounds, such as *p*-amino-phenol; but they are likewise formed by means of certain mono-substituted derivatives of benzene, such as analine. It is this process which is used in laboratories for the preparation of ordinary quinone, chromic acid being the oxidizer.

Among the principal properties which influence tanning are the following:

Quinone is only slightly soluble in cold water (0.5 per cent). It dissolves better in hot water and in acidulated water. In practice it is dissolved in slightly acid boiling water . . . but the operation must be performed in a closed container since the product is very volatile and is easily carried off by the steam. Acid solutions remain unaltered longer than either neutral or alkaline solutions, especially the latter. Light is unfavorable, facilitating oxidation. Quinone solutions must not come in contact with metals or wooden containers when the latter contain tannin or when the vat has been previously used for tanning with vegetable tannins, since otherwise their color will become much more intense and they will lose their property of producing a light tan. Quinone keeps well in the crystalized state in wooden or tin containers *when dry.* It is preferable to prepare the solution beforehand, making sure that they contain no undissolved quinone.

Application.—Quinone alone will tan the hide completely in a few days, 1.5 parts of quinone being employed for 100 parts of raw skin. At first sight it would seem, however, that quinone tanning is the ideal process both because of its rapidity and because of its cheapness. However this is not true in the present state of the leather market. Aside from a few kinds of light leather . . . leathers are sold by weight. This custom was established at a period when the raw skins could be bought at a price moderately higher than that of the tannin. . . . Since then the situation is changed—green hides with the hair on are sold at a formidable price, and the disproportion between its value and that of the unit of tannin . . . has become considerable. The result is that leathers, especially those made by rapid processes, contain more or less combined or non-combined tannin, so that many of them often contain no more than 30 to 35 per cent of the substance of the hide itself. Under such conditions quinone tanning cannot compete with tannin by vegetable extracts, except in the case of light leathers which are sold by the square foot. . . . The chief use of quinone in fact is for *pre-tanning.*

Even before the discovery of quinone formol was used for the pre-treatment of leather in order to isolate the fibres from each other and give them the desired firmness and resistance, enabling them to bear the action of the highly concentrated solutions used in rapid tannin. The formol does not persist in the leather and experience has shown that after being stored for a few months these leathers become brittle. Quinone does not produce such an effect and the hides treated with it fix the vegetable tannins with remarkable rapidity without affecting unfavorably either the leather or the modern rapid process, hence its use has rapidly spread . . . especially in the tanning of sole leather.

Quinone pre-tanning is used in preparing strap leather as well as heavy leather and glossy leather, experiments having shown that this treatment enables it to undergo resistance to traction longer than usual. It is also used for vamp leather and for leather prepared by vegetable tannins as also in mixed tanning together with chrome.

In preparing box calf . . . the quinone is applied in the presence of lactic acid, 600 gr. of quinone and 300 gr. of 80 per cent lactic acid, applied three times, being sufficient for 100 kg. of hide. If the hide has undergone the bran treatment the lactic is useless; acetic acid is better for the ordinary leathers mentioned above.

Chrome tannin is obtained in a bath, the quantity of chrome generally employed being reduced to 6/10 of the amount. The amounts of borax, of sodium bicarbonate, or of the ammonium mixture required for neutralization are likewise reduced in the same proportion.

Black box calf thus produced has the following advantages:

1. The leather is more pervious to air, making cooler and more hygienic shoes.

2. It is more pliable and the bloom is finer. . . .

3. The black color is more uniform, not only in the different parts of the same hide but also in the same lot of hides which increases the percentage of first class leather. To produce the box calf color the proportions required of sumac and of gambier can be greatly reduced, and the bloom is never either hard or brittle. The same thing is true of glossy calf, either black or colored. Finally the tanning of kid skins for shoes can be performed in a bath and the application of the color does not require previous testing.

NERADOL-D. OR SYNTAN.

The Work of Stiasny.—Stiasny's purpose was not merely the replacing of natural tannins by other tannins (industrially speaking) of much simpler character like quinone, but the preparation by synthesis of substances resembling natural tannin as closely as possible.

Such products must have a well defined composition which can be modified at will by the introduction of new alkyl groups, with the view of manufacturing an entire series of tannins specially suitable for obtaining all known varieties of leather and even other kinds as yet unknown. The use of these tannins, to which the inventor gave the name of "syntans," was intended to remedy the more or less empirical character of tanning by vegetable tannins . . . by producing compounds of known composition and definite action.

Stiasny presented his first communication upon this sub-

ject in 1913 to the London Society of Chemical Industry, of which paper we here give the following abstract:

The syntans are products of condensation. They are obtained by heating the phenols with formaldehyde in a slightly acid solution and then rendering insoluble the resinous substances thus obtained by the action of sulphuric acid. They can also be prepared by sulphonizing the phenols and then condensing them with formaldehyde under such conditions that products soluble in water are alone obtained. According to the inventor the condensation process properly consists in the formation of a derivative of diphenyl-methane, which by polymerization leads to the formation of molecules having a high molecular weight, which fact imparts its amorphous character to the product.

Syntans resemble in aspect tannin extracts but are less highly colored. Their aqueous solutions are semi-colloidal and traverse semi-permeable membranes only with great slowness.

They precipitate gelatine. Together with salts of iron they produce a deep color. They are precipitated by lead acetate and by hydro-chlorate of aniline. Finally they tan skin like true tannins.

Neradol-D (which up to the present time is the principal product put upon the market) when employed alone yields a very pliable leather, having a characteristic light color. It is used in combination with other tannins for the pre-tanning of heavy leather in the same manner as quinone. Like the latter it protects the bloom which it tans slowly; the latter does not break after tanning with strong extracts and it is but slightly sensitive to the later action of light. Finally it accelerates the process of tanning and does not interfere with the yield by weight. . . . Its use is recommended for the retanning of Indian sheep-skins and also for simultaneous employment in chrome tanning.

The author here comments upon the lack of detail given by Stiasny, remarking significantly that in 1912 he had sold his patent to the "Badisch Company, Ltd.," which firm placed the product upon the market under the name of Neradol-D.—Editor.

PREPARATION OF THE SYNTANS.

At the beginning of the war the German-made Neradol-D disappeared from the English market. It was then noted that it had enjoyed a very wide use and products were thereupon prepared from the data given in the patent, which differed considerably from each other according to the manufacturer. The color of these products varies from red-brown to black and the consistency from the fluid to the pasty condition. All of them contain non-soluble substances in considerable proportions and appear to behave in practice like Neradol-D.

The raw materials used consist of cresol C_6H_4 (CH_3) OH (which is found in coal tar), sulphuric acid, formol, and caustic soda.

The testing of these substances is quite easy except as regards crude cresol which not only contains the three isomers of this body, but also variable quantities of other phenols, of pyridin, etc. The latter remains in the form of the sulphate during the operations and does not influence them.

The manufacture occurs in three phases—sulphonation, condensation, and neutralization . . .

a. Sulphonation. A mixture of equal weights of cresol and sulphuric acid is heated until complete sulphonation occurs . . . The time required varies from 1½ to 8 hours according to the nature of the raw material, temperature, etc. . . .

b. Condensation.—This process, which is performed in the cold, is slow and tedious, and it is difficult to tell whether the reaction occurs under good conditions. All that can be determined positively is the complete disappearance of the phenol odor which is replaced by the vapors of formaldehyde.

The sulphonated product is then cooled, after which formol is poured into it *very slowly during continuous stirring,* care being taken to keep the temperature below 35° C. and regulating it either by a worm or by a double wall wherein water or some other liquid, kept as cold as possible by a freezing machine, circulates. The addition to the solution of formaldehyde causes a considerable rise of temperature, both because of the heat developed by the reaction and because of its mixture with the concentrated sulphuric acid thus produced.

The substance obtained is very viscous, and has a dull brown color of a slightly redish cast. This is hygroscopic and must be neutralized without too great a delay.

c. Neutralization.—The product contains about 25 per cent of acid calculated in sulphuric acid. It is partly neutralized so as to reduce the acid approximately to the content of a normal solution, i.e. 4.9 per cent of sulphuric acid. The quality of soda solution required must be calculated separately for each vat. The heat developed by the reaction is considerable; hence the soda solution must not only be added very slowly with constant stirring but the mass must be cooled externally as described. Under these conditions the liquid clears up greatly and loses a large part of its viscosity.

It is possible that by causing the temperature of the neutralization to vary as also the concentration and the proportion of the soda solution, secondary reactions are made to take place which produce changes in the nature of the compound obtained to such an extent as to cause a greater or less degree of variation in the latter's properties. . . . At any rate compounds are obtained which, while behaving similarly to Neradol-D differ considerably with respect to the results obtained in tanning. Some of the products manufactured in England are, in fact, superior to Neradol-D, yielding leathers which are whiter and more pliable although equally resistant. Furthermore, these products are capable of penetrating the calf skin in the course of only a few hours.

The author here quotes an abstract of certain articles published in "The Leather World" with regard to different practical methods of the employment of these products. Since these are not necessary to the comprehension of the scientific aspect of the subject, we omit them in this place.—Editor.

THE FUTURE OF SYNTHETIC TANNINS.

The so-called synthetic tannins, quinone and syntan, have permitted the obtaining during the war of leathers of good quality by rapid methods. Such methods have been almost completely substituted for the older methods over which they present many and important advantages. It cannot be doubted that these new methods will continue to make progress in the future. . . Since 1914 the allied countries have enormously developed the industry of coal tar and its derivatives, their object being to prepare explosives in the first place and secondly the dyes and medicines formerly furnished by Germany.

It is probable that the industry of derivatives of coal will continue to be extended after the war and that raw materials for the manufacture of synthetic tannins will be obtainable in abundance and at a fair price. . .

* * * * * *

It must be mentioned, however, that the technical reviews have frequently referred to the difficulties encountered in the manufacture of leathers by the use of syntans. In Germany in particular the authorities have even gone so far as to prohibit their use in the manufacture of leathers to be used for the army. Furthermore, the latest researches concerning natural tannins and particularly those made in Germany, seem to prove that these substances contain quinonic groups, which play the principal part in tanning. According to Moeller (*Collegium* 1918, pp. 71-78) all the various kinds of tanning possess points in common with quinone tannin and all the tannins have a quinonic character.

The phlobaphenes of quebracho, in particular, yield anthracene, when distilled with powdered zinc, and more than ten

years ago Nierenstein ascribed this reaction to the presence of a hexa-oxyanthraquinone. Powarnin discovered oxy-anthraquinone in the tannin of willow bark, which is a pyrogallic tannin. As a matter of fact all of the phlobaphenes formed by the dehydration and oxidation of tannins contain quinonic groups in their molecules.

All tannic extracts contain these compounds, which are kept in solution by the pepsinizing action of tannin. When the latter is oxidised the colloido-chemical character of the solution changes. Certain pepsinized phlobaphenes are precipitated at the same time as the black humic substances proceeding from a more profound dehydration. The latter are partially absorbed by the phlobaphenes remaining in solution, which is the cause of the deepening in color of the liquid. Furthermore, the soluble pepsinizers are converted into colloidal substances closely resembling the phlobaphenes. As an intermediary product of this oxidation one always finds benzo-quinone, the quin-hydrone which imparts to the solution an intense red color, a hue which is often attributed to the phlobaphenes themselves.

According to Moeller any oxidation of the pepsinizers in solutions of vegetable tanning substances will yield, as intermediary products, quinonic compounds, and these compounds may even be preexistant in the plants themselves. But substances, having a quinonic character possess in a high degree, the property of forming coloidal pepsinized solutions, and are, in reality, the true and only tanning substances capable of uniting with the fibres of the skin permanently. The facts stated in the foregoing remarks, as well as the present concept of the nature of the art of tannins appear to indicate that the quinone process constitutes the method which accomplishes in the simplest and probably in the most rapid manner, those phenomena which take place in the process of tanning by means of vegetable tannins.

INDUSTRIAL APPLICATIONS OF HELIUM

The rare gas helium was long considered of merely scientific interest because of its scarcity and the great expense of its production. In the last few years, however, helium has been found to be present in the emanations issuing from numbers of hot springs and in the explosive gas, often present in mines, known as fire-damp, or in so-called natural gas. Furthermore, the war has given a tremendous impetus to the study of helium and the effort to produce it more cheaply than was possible while it remained a mere curiosity of the laboratory. The reason for this, of course, is the fact that it is admirably adapted for the filling of the gas bags of dirigibles and other balloons, because of the fact that it is non-inflammable and non-explosive like hydrogen, which has hitherto been empolyed for this purpose. Helium is likewise very light, only about twice as heavy as hydrogen, which is the lightest of all known substances. One liter of helium weighs 178 milligrams.

The ascensional power of helium is about 92 per cent. that of hydrogen. This comparatively small diminution of power is practically insignificant, being largely compensated by only half as much diffusion through textiles. Another valuable property of helium resides in the fact that it can be more readily traversed by electric discharges than is the case with most gases. For this reason an appartus may be employed inside the aerostat to heat the gas by electricity and in this manner by modifying the volume of gas it is possible to vary at pleasure the ascensional force, which is of course eminently useful.

Up to a few years ago only two or three cubic meters of helium had been produced and the cost was something like $40,000 per cubic meter. Recent achievements in the production of helium in this country and elsewhere are interestingly summarized in a recent number of Larousse Mensuel (Paris), from which we abstract the following remarks:

At the instance of an engineer named Cottrell well known in France through his work concerning the collection of dust by electricity, important plants were erected in 1918 in the United States for the extraction of helium from natural gas. These efforts were so successful that when the armistice was declared 5,000 cubic meters of helium were ready to be delivered for use in military balloons. The gas from which this helium was obtained was found in a well at Petrolia, Texas, having a daily flow of 700,000 cubic meters of natural gas. This gas (which is composed chiefly of methane) contains 0.9 per cent. of helium. It is piped a distance of 150 km. to Fort Worth and Dallas.

The helium is separated out by a process of liquifaction in the same manner in which liquid air is produced. The three methods in practice, those of Claude, Linde, and Jefferies-Norton were employed in three distinct plants, in order to determine which process was most advantageous. These plants succeed in producing helium 93 per cent. pure. The purified gas is used for fuel while the helium is compressed and stored in steel tubes.

It is to be hoped that this interesting experiment will not be arrested by the coming of peace. It is reported, indeed, that projects are on foot in America looking towards the annual production of 500,000 cubic meters of helium and an accompanying reduction of the price to less than four dollars per cubic meter.

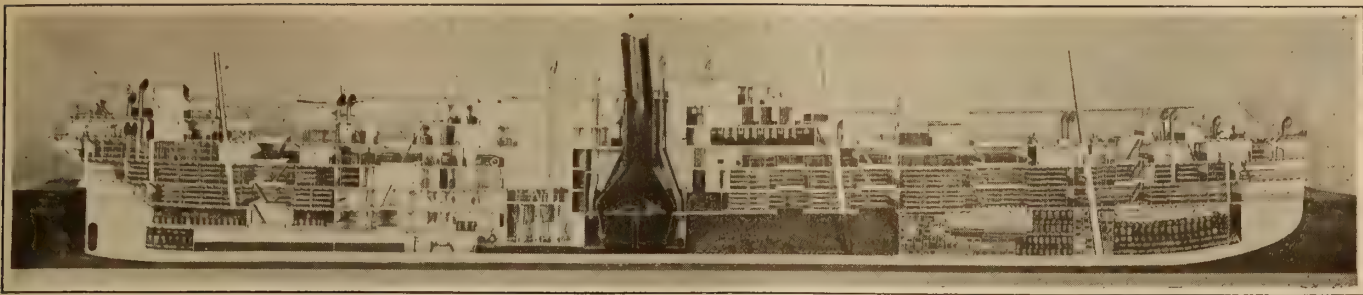
The production of helium at practical prices is closely dependent at present upon the development of the dirigible. The latter loses one per cent. of its contents per day through diffusion, which makes it a steady customer, so to speak, and raises the question of where sufficient supplies of the gas can be obtained. We have already spoken of natural gas as a source in this country. In France Prof. Mouren has shown that considerable amounts of helium exist in the gases issuing from hot springs, sometimes as much as 10 per cent. It is also found issuing from the ground in volcanic regions, and such supplies may perhaps be regarded as practically inexhaustible.

A practical difficulty arises, however, with regard to the production of helium which may be stated as follows, If production from natural gas is deferred until the helium is actually required this involves deferring the use of the natural gas as a combustible—and this at a time when it is more needed than ever; on the other hand if the helium is extracted and stored till wanted the cost of storage would be prohibitive.

According to the writer of the article in Larousse, the solution of this dilemma must be sought either in the promotion of the commercial use of the dirigible or in some new application of helium which will increase the demand for it. Not long ago M. Claude, whose name is well known in connection with the liquifaction of air, having proved that the atmosphere contains three parts of neon and one part of helium in 200,000 parts of the atmosphere, conceived the idea of making use of the helium by employing it to drive a motor by means of expansion, and thus being able to obtain in practice temperatures very close to the absolute zero.

At such temperatures the physical properties of bodies are so greatly modified that numerous practical applications may be derived therefrom—a typical example is the reduction of electric resistance to one-ten-millionth of its value. Furthermore, these endeavors to produce helium in practical quantities may have the happy result of facilitating the producton of oxygen, thanks to the improvement made in liquifaction processes.

Hitherto oxygen has been so costly that its use has been restricted to certain special purposes, such as welding, perforation, the blow-pipe, etc., but if it could be furnished to manufacturers at a reasonably low price it is confidently predicted that a revolution in metallurgical processes would ensue, and that we might have furnaces fed with oxygen instead of with air. Thus helium furnishes us with another example wherein pure science serves as a handmaid to practical industry.



A HALF MODEL OF THE "GENERAL SHERMAN," SHOWING THE INTERESTING DETAILS OF A GOVERNMENT TRANSPORT. QUITE TEN THOUSAND PIECES WENT INTO THE MAKE-UP OF THIS MODEL

Ship Building in Miniature

Important Part That Models Have to Play

By Robert G. Skerrett

(Photographs copyrighted by the Keystone View Co.)

SHIPYARDS on the waterfront are matters of commonplace, but a marine construction plant tucked away high above bustling thoroughfares is, indeed, something of a novelty. And yet, in a tall loft building on lower Manhattan, in Greater New York, is an establishment where all kinds of craft that float, from small boats to superdreadnaughts, are turned out complete in every detail.

More than that, there is no other shipyard in the whole country boasting departments enough to supply on the spot, as the concern in question does, the multiplicity of things needed from the time of the laying of the keel until the fluttering colors at masthead and peak indicate readiness for service. True, the vessels produced are not designed to defy storms and to force their way onward against pounding seas, but in their way and field of usefulness they are not disassociated from their water-borne kindred that do battle with the changeful elements. Lest the foregoing mislead, let it be said that we are speaking of nautical models, of the naval architects's creations in miniature.

Popularly, the model of a ship is looked upon more often than otherwise as an expensive toy—a plaything in a measure that may be extremely ornate and decorative but in no wise of practical value. The gentry that count their pennies over carefully are prone to ask, "What's the use of the thing?" And then positively dismiss the matter with the vocal protest, "All a waste of money!" For the sake of those likely to be influenced by this hasty attitude, it might be well to go back two or three centuries for a start and then trace the evolution and the reason for being of miniature replicas of ocean-going craft of all sorts. We shall see that the utilitarian impulse has played a prime part for a long, long time while in their fabrication.

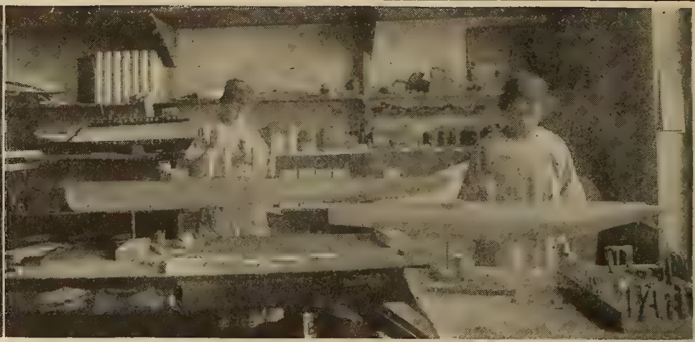
In the days when the British Admiralty was first busy upbuilding the nation's sea might, in the generations gone when the naval architect boasted no more exalted title than master shipwright, the authorities would have thought they were tempting Fate to start the building of their "oaken bulwarks" without some concrete evidence of how their frigates and their line-of-battleships would look when finished. Indeed, they would hardly have known how to carry on correctly the work of construction unless guided by a model in detail. It was this practice that brought into being the myriad models that now adorn the home of the Admiralty and certain British museums. These miniatures were for a considerable period the basis of such plans as were prepared, and furnished certain information of their own by which the ship carpenters and the shipwrights of those days could visualize just what they were expected to do.

To this end, little was left to the imagination, and a deal of painstaking care was exercised in developing on a much-reduced scale every important structural feature. Therefore, the outside planking on one-half of the hull below the waterline was pretty generally omitted so that the frames, the keel, the keelsons, the floors, the deck beams, etc., could be seen in their true relation to one another, and each with its distinctive shape agreeably to its position in the complex

CHECKING UP THE HULL CONTOURS WITH A TEMPLATE REPRODUCED FROM THE BODY PLAN

FORMING THE MASS OF "BLOCK" FROM WHICH THE HULL OF A MODEL WILL BE WORKED

PUTTING THE FINISHING TOUCHES ON THE MODEL OF A CONVERTED YACHT WHICH PLAYED A PART IN THE WORLD WAR



PAINTING WAR TIME NAVAL MODELS—ONE OF OUR BIGGEST SUBMARINES AND AN UP-TO-DATE DESTROYER

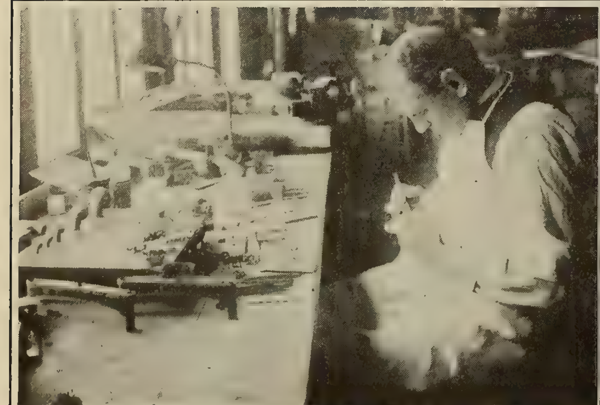
framework. On the other half, the planking would possibly be complete from the keel to the upper limits of the hull. And thus the "lines" or contours essential to flotation and relative ease of propulsion under canvas could be measured and reproduced on the mold-loft floor so that the man with the broad-ax might fashion his timbers for the full-sized vessel.

The model maker was a product of the period and, as often as not, was a qualified shipwright who possessed special skill in the handling of refined tools. He would take his block of wood or materials and lovingly and patiently work them into shape—grace of line and accuracy of detail being the result of an experience which made him familiar with the body forms which would give adequate speed and seaworthiness. At a later date, as a knowledge of interpreting drawings grew, the advance model became a simpler product, because the shipworkers were not so dependent upon miniature details. It was then sufficient to supply a solid half model, showing the outer aspect of the bare hull from stern to stern and from the keel up to the exposed decks. From these half models, the men of the mold-loft developed the lines and contours of the craft's body, and, so guided, the woodworkers fashioned templates or patterns for the multiple elements of the structural framework.

These half models were fashioned out of a built-up block composed of successive layers of wood of equal thickness held together by dowels, the meeting surfaces of two contiguous "lifts" representing a waterline at a definite point above the keel. After the block had been cut and chiseled into the desired form, then it was an easy matter to take the model apart, layer by layer, and transfer each waterline to paper. With this done, the ship carpenter could readily check off the dimensions at every point on the hull and make the full-sized part in accordance. With those half models as basic records, and with the knowledge of how the actual craft later performed, the designer of those days was able from time to time to effect improvements despite the fact that his procedure was so largely a matter of "rule of thumb." Native cunning and intuition, a cultivated appreciation of "sweetness of line" through feeling, and a keenness of eye made the model then a potent aid in the building of ships.

As the science of naval architecture advanced, the designer was inclined to belittle the value of models, and, because of his wider knowledge of mathematics and the technical development of graphics, he came to rely wellnigh entirely upon paper and pencil. During the prevalence of this attitude many disappointing vessels were put overboard, for somehow either the lines were not faithfully reproduced in the yard or, if they were, they disclosed the fact that the man originally responsible for them could not visualize the consequence of his choice. It is a rare mind that can picture the third dimension from lines that symbolize only length and breadth, for instance. It was inevitable that shipbuilders should come to realize that much might be gained by combining the stories to be told by both drawings and models. This was quickly emphasized when iron, and, later, steel more and more took the place of timber in the fashioning of waterborne craft.

The modern ship, whether naval or commercial, is made up of assembled plates, angle bars, and beams of steel. Knowing as the ship designer does today how much may depend upon a vessel's form in the matter of speed, and the propulsive effort needful to attain it, mere drawings, with all of their elaborateness, are no longer accepted as conclusive. Therefore wooden models are made not only for testing in towing tanks but others, scaled usually to a quarter of an inch to the foot, are produced to facilitate certain essential calculations and to enable the "office" to order the hull plating, etc. Naturally, these models must be fashioned with precision, for any error would be multiplied forty-eight times in every foot of the intended craft. The models also serve to give the designer a three-dimensional appreciation of his problem and aid him in securing that balance of



THE METAL FEATURES OF A MODEL REQUIRE THE SKILL OF AN EXPERT MACHINIST

THE MINIATURE GUNS OF OUR FIGHTING CRAFT MODELS ARE WONDERFULLY COMPLETE IN THEIR OUTWARD DETAILS

mass and features essential to strength, correct functioning and appearance.

As experience has taught us, it is not difficult to draw a circle and to say that it represents the outline of a globe, but it is quite different to decide from that figure just how to proportion and to shape a single piece of material that can be bent or pressed into the form of a sphere. Of course, if you have a ball upon which to fit your pattern a little practice will enable you to do the trick. The external plating of a vessel is the skin that must conform to the changing lines and contours dictated by the underlying steel ribs or frames, and this plating, in multiple units of divers forms, must be ordered in advance of construction.

A properly-scaled wooden model of the hull of the craft to be, with sandpapered unpainted surface, is turned over to some of the drafting force, who indicate on the bare pine every plate from bow to stern and from keel to sheerline. It is then a relatively easy task to take off the "expanded" dimensions of curved surfaces and to give their measurements as flat plates. These figures are then sent to the steel mills where patterns are made and the plates are cut accordingly. Later, when they reach the yard, these parts are heated and hammered or otherwise bent to fit. By means of the wooden model and the advance measurement of materials which it makes possible, the naval architect computes what all of this steel will weigh, and this enables him to determine the ultimate displacement of his craft and to estimate pretty closely some of the costs.

Subsequently this bare model of the hull is carried a stage further and some of the dominating deck features, etc., are put on. If a fighting ship, this procedure is very desirable because it enables the designers to determine quickly the possible angles of fire of guns without inviting interferences with other necessary structural parts. In short, it gives positive information about interrelated characteristics and makes it practicable for the naval architect to avoid mistakes that may later on entail heavy outlays to correct. Similarly, in the cases of merchant and pleasure craft, by following much the same course, vessels can be planned confidently so as to insure a maximum of comfort to passengers and convenience to the personnel operating them.

It has been the custom wellnight since the birth of our modern navy to employ models of the foregoing description and, after they have served the designer's purpose, to complete them and finish them outwardly as miniature replicas of their service kin. The object has been twofold: first to record thus in the most expressive way the development of our battle fleet and the gradual growth of the distinctive types of war craft—the adoption of a uniform scale of a quarter of an inch to the foot facilitating accurate comparison in the matter or sizes. For some years, all of these models were made at the Navy Yard, Washington, D. C., but now some of them are being built at the plant in New York City over which Mr. Horace E. Boucher presides. This expert—one may rightly say of this artist—was for a number of years in charge of the naval model shop in the National Capital; and his establishment in Manhattan is probably the largest and best equipped plant of its kind in the United States.

As the illustrations accompanying this article indicate, Mr. Boucher makes more than marine models, but the purpose of all of these creations is to supply the element of the third dimension and to permit both the technical and the nontechnical observer to visualize the relations of things and to get a sense of proportion. The habit is strong with all of us to query, "How does the thing work?" It is the survival of our earlier days when we wanted to pry into a watch or clock to see the wheels go round. The picture of the longitudinal section of the army transport "General Sherman" shows that it is possible to get speedily a comprehensive grasp of the whole interior of that vessel and to see to what purpose the various compartments and sections are devoted. An examination of the model, itself, gives a still greater wealth of structural data—details that reveal just how much thought must be given to the planning of a ship so that every department may serve its end to the best advantage and that all available space may be put to good account.

But we cannot flatter ourselves that we have been the pioneers in helping the rightfully inquisitive to learn through such mediums about the internal get-up of full-sized vessels. As a matter of fact, we have not carried this educational work anything like as far as wisdom would suggest. Whether we like it or not, the Germans have led by a long way in this realm of enlightenment. Sixteen years ago, our naval attaché at Berlin informed us that all of the Kaiser's warships were furnished with skeleton models for the instruction of their personnels. The German Admiralty recognized that it was very desirable that everybody aboard a fighting ship should be familiar with every phase of its construction and equipment. The Teutons did this because they were aware that drawings and blueprints are not readily understood by the sailors and that even the officers frequently found it hard to grasp their meaning.

Further, the interior of a ship is a complex network of compartment and lesser subdivisions, and many of these are isolated from one another so that a man in one space cannot step readily through a door into a neighboring one and thus

A MODEL OF THE TROY LOCKS OF THE NEW YORK STATE BARGE CANAL

get an understanding of their degree of association. He must travel up a ladder, through a hatch, and possibly around a number of obstructions before he can make his way down into a near-by compartment—confusing the while his sense of relationship. The skeleton model, on the other hand, which permits deck after deck to be lifted off and allows the observer to see successively just how a craft is fashioned and is interdependent, makes it feasible for all but the utterly stupid soon to master every essential detail of his ship. The Germans did not hesitate to promote this knowledge by supplying models costing anywhere from $500 to $2,500.00.

The same naval attaché was later ordered to the Asiatic Station to command the U. S. Monitor Monterey; and it was not long before it was impressed upon him that it was very desirable for him to know his ship in the fullest sense of the term—to be familiar with the positions of all watertight compartments, the arrangement of the double bottom, and the leads of a multiplicity of pipes having to do with safeguarding against disastrous leaks, the proper ventilation of out-of-the-way areas, and the distribution of motive steam—not to mention that network of nerves in the form of electric wires and conductors. For $110 in gold he got three Chinese carpenters to build him a beautiful and exact demountable skeleton model of the Monterey; the ingenious Orientals using the simplest of materials to fashion the miniature—cunningly requisitioning macaroni to serve for piping and valves, and

coloring each of these to indicate the particular system to which it belonged.

At the U. S. Naval Academy, models of vessels have played their part for years in the education of our midshipmen, and by them our embryo admirals have been able to comprehend technical features and operative procedures which otherwise might have puzzled them sorely. The array of full models and the still more numerous half models there tell their own story of how our naval constructors in the decades gone have felt their way before risking the nation's funds in the buildiig of the actual craft. Finally, the so-called handsome display models generally built by the Bureau of Construction and Repair of the Navy Department have proved of the utmost value in bringing vividly home to our inland citizenry an understanding of our fighting fleet—thus serving to promote a necessary interest in our seagoing defenses and to stimulate enlistment.

Big steamship companies are fully alive to the psychological appeal of a miniature replica of their passenger craft, and all of them know that the thousands of dollars expended in this way are richly repaid in patronage. Foreign lines have been especially shrewd in thus reaching first our imagination and next our pocketbooks. A third reason for ship models is a sentimental one; and this is apt to grip strongly the yacht owner. It yields him no end of quiet delight, when the days of cruising are halted and his craft is hibernating in some snug harbor, to look upon the little model and bring to mind vividly every detail of weeks and months of enjoyment and to arouse again the fascination of measuring strength with fickle winds and treacherous seas. A picture would only give a small part of this satisfaction because of the flatness, the two dimensional character of the mediums of expression. The model, on the other hand, he can scan from all angles and revel in an ever-changing point of view.

In building the "block" of a model seasoned white pine of the finest sort is used. The block is formed up of a series of planks so wonderfully smoothed that their surfaces come together throughout, and, under moderate pressure, exclude the air. As a result, the thinnest film of glue is essential to establish a vacuum and to bind the successive layers or lifts into a single mass. Before they are united in this fashion, the contours are traced in pencil upon the planks, and frequently the lifts are sawed approximately to shape. Next, the woodworker cuts away the pine carefully until the penciled contour at each waterline is brought to light, and then he clears away the material between neighboring water lines, checking up the body form from time to time by little templates of the different curves at prescribed positions, usually from keel to deck upon definite frames. When the lines are true in every particular, the skin surface of the hull is smoothed to a nicety by sandpapering.

While the woodworkers are busy at their respective tasks, the metal-workers are engaged in fashioning with amazing fidelity to detail a varied array of fittings and equipment. With infinite cunning they call into being mooring bits, hawse pipes, davits, boat cranes, windlasses, winches, searchlights, guns, ventilator cowls, smokestacks, anchor chains, etc. In many respects their products call for manual skill greater than that of the jeweler. A few of these features can be cast, but many of them have to be wrought by lathe or patiently created by tool, blowpipe, and the smallest of soldering irons. For the most part brass is the basic metal; and if the full-sized replica is of brass, then the fitting is polished and plated with gold to hide the traces of solder. Nickel plating coats the fittings that would be of polished steel or nickel in the full-sized craft; and tinning is the model's substitute for galvanized-iron equipment.

But before the metal features are placed upon the model, the hull, superstructure, deck houses, etc., must be colored in perfect accord with their corresponding portion of the full-sized vessel. Some idea of the painstaking work entailed can be gathered from the fact that the hull may receive anywhere from five to eight coats of paint, and each coat is rubbed down before the next is applied. Ultimately the miniature is varnished, and this, too, is rubbed and rubbed until it is impossible to detect the slightest trace of brush stroke. With the body of the wee craft ready for its fittings, then these are put in place with precision, and the care exercised must accord with a scale that crowds into only a quarter of an inch the equivalent of twelve inches. A few hairbreadths of error might spoil the interrelation of a number of features. Finally, masts are stepped, stays, signal yards, and running rigging are set or rove. Tiny boats are fixed in their chocks or hung at the davits—the blocks and falls faithful in every particular. No wonder, some models may be composed of 10,000 or more pieces, for neither Mr. Boucher nor a knowing critic would be satisfied if anything were missing or if any fitting seemed lacking an essential working detail.

The layman should not be astonished to learn that it takes the joint efforts of a considerable force of expert craftsmen and weeks and months of continuous work to produce a complete display model. The determining factors are the size of the real vessel and the variety and number of her characteristics and equipment. The so-called miniature may be but a few inches long or, in the case of a dreadnaught or ocean greyhound, may measure from bow to stern from 12 to 20 feet. The cost of these beautiful productions runs from $300 up to $12,000 or more.

DEMONSTRATION COAL MINES.

By J. J. Rutledge,[1] McAlester, Okla.

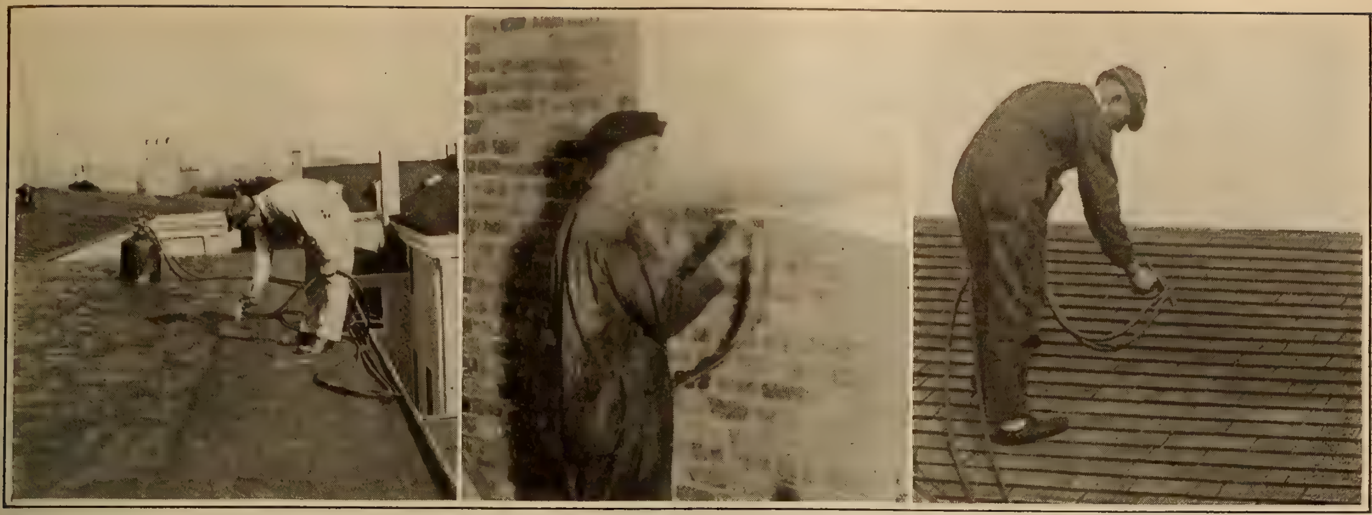
The United States Bureau of Mines established at Bruceton, Pa., in 1909, an experimental mine for the purpose of testing the means of preventing and limiting mine explosions. During the last ten years, numerous explosions have been caused to originate in this mine for investigative purposes and the rate of propagation of the explosion wave, the pressure developed per unit of area by the explosion, and the general results of the explosions have been carefully recorded and studied. Means of preventing mine explosions or of limiting them to the areas in which they originate have been developed. A great deal of valuable information has been derived from the work in this mine and much more useful and valuable information will be obtained in the future. The writer would plead, not for the opening of experimental mines in all the important coal-producing fields in the United States, but for the opening of demonstration mines, or mines in which experiments could be made with the various details of coal mining.

Owing to competition in the same markets, small capitalization, or low profits, it may be an utter impossibility for any one company to try a new method of mining. Labor conditions may prevent the trial of a new method of working. It may be impossible or inadvisable to disturb existing working conditions for fear of causing trouble among the miners through real or fancied changes in the scale of wages.

If a certain method or plan of working had been shown to be the safest and most efficient, public opinion would force coal operators to adopt the new methods of working, if they did not do so voluntarily, and public opinion would also furnish moral support to the operators in overcoming any opposition that the miner and other employees might manifest toward the installation of the new and better method.

If a new method was found to be safer and more economical than the one in use, the authority of the state could be invoked to support any operator who desired to adopt it. Very few coal-mine operators would dare run counter to public opinion, even were they to ignore the financial benefits to be derived from the adoption of the new plan. Compensation insurance companies, through their mine inspectors, would give credit to those mines that adopted the new methods with the result that their liability insurance would be materially reduced in cost.

[1]Mining Engineer, U. S. Bureau of Mines.



EXAMPLES OF SPRAY PAINTING, SHOWING A WIDE VARIETY OF APPLICATIONS

Spray Painting*

A Study of the Practicability of Blowing Paint on Various Surfaces

By H. A. Gardner

THE war placed such great demands upon the painting industry that it was found necessary to utilize every means to accomplish the huge painting program that developed. The shortage of men capable of wielding brushes soon became apparent and the great speed demanded in production developed as a vital factor. As a result, the steel hulls of many vessels, the rough siding of many temporary buildings, and the surfaces of thousands of guns, tractors, and other military equipment were coated by the spray machine. Because of the speed obtained through the use of this device for preserving or camouflaging materials of warfare, attempts have been made to develop it for peace time painting purposes. To many observers the question has come as to whether the machine is of sufficient practical value to merit a permanent place in the art of painting and whether it will to any extent replace the old-time hand paint brush.

Some observers have stated that hand-brush manufacturers cannot produce sufficient brushes to apply the paint for which such great demands exist. While the apparent shortage of bristles might to some extent be held responsible for such a situation, it has been suggested that even though bristles were as plentiful as at any time previous to the war, it would be difficult for manufacturers to produce an over-abundance of brushes for coming needs, and that the brush industry could not therefore be injured through the development of the spray-painting machine.

Similarly it has been advanced that the occupation of the journeyman painter could not in any way be injured by the adoption of spray painting for certain special classes of work, since it is often impossible to obtain sufficient labor to apply the paint for which such enormously increased demands exist. Furthermore, it has been claimed that unless some means is provided for at least partially relieving the situation, millions of dollars of loss may result from the surface decay that will take place on unpainted structures. It is undoubtedly true that painting was neglected to such an extent during the war period that immediate action must now be taken to preserve the property that will otherwise be damaged if longer left unpainted. This means that during coming years an even greater demand will develop for paint and varnish products. Any legitimate and satisfactory means for the application of these products should therefore be welcomed not only by the master painter but by the journeyman painter and the public. The use, for instance, of the spray machine (if found practicable) will not only be of service to the property owner but will actually stimulate the employment of and demand for painting labor. To make this more clear, it has been suggested that a comparison of the situation be drawn with the effect of the sewing machine upon the tailoring industry. The journeyman tailor undoubtedly at first loked askance at the development of such a machine. It was soon found, however, that this machine created an almost entirely new industry in the production of ready-made clothing. The availability of these products at once effected a great demand and increased usage. As a result, thousands of operators were required where but hundreds were employed before.

It is believed, therefore, that any device that creates new business in new fields is to be given the hearty support of all, if found to be of a practical nature. Whether or not the machine will prove useful will depend upon the results obtained by the painter during the coming period of great activity in his trade. He may, for instance, find it well suited for certain classes of work and unsatisfactory for other kinds.

Some observations made by the writer on tests with the spray painting machine may be of interest to the members of this Association in judging of its possible usefulness in their work. The tests were made on large surfaces with both hand brushes and spray machines. After a sufficient period of exposure, data will be available as to the comparative durability of each type of work.

SPRAY PAINT TESTS AT WASHINGTON.

The tests referred to were made in Wahsington on government buildings by one of the prominent members of this Association. The machine used in the experiments consisted of a 4-H. P. motor, a large air tank, and a 5-gallon paint tank. It required 220-volt direct current. For the roof work the paint tank was hoisted to the roof and two hose leaders were carried from the air tank located on the ground. Two operators could work at the same time with the paint tank which was fitted with two spray guns.

*Paper presented at the convention of the International Association of Master House Painters and Decorators of the United States and Canada, New York City, February 12, 1920. Copyright 1920 by H. A. Gardner.

For the exterior work an experienced spray brush operator started the work on one side of the building, and two journeymen with 4½-inch hand brushes started the work on the other side, which was a duplicate in size, shape and construction of the side selected for the spray test. After the work had been started a journeyman painter entirely unfamiliar with the use of the spray gun was shown how to operate it. He completed the tests, including the walls and roof area. It was apparent that a very short period of time was required to instruct a man to use a spray gun. The tests were of good size and included on the side walls an area of over 8,000 feet and on the roof an area of nearly 9,000 feet.

The paint used for the exterior wall work was a lead paint tinted with ochre, weighing 17.6 lbs. per gallon for the first coat and 20 lbs. per gallon for the second coat. Both paints were easily handled by the spray gun. The paint used on the roof was an oxide of iron paint weighing about 14 lbs. per gallon. The paint used for the interior work was a modern sanitary flat wall paint of the lithopone type, weighing 14 lbs. per gallon. It was apparent that the spray gun would successfully handle paint of practically any weight per gallon.

In doing the first coat on the exterior brick walls, all cornices and trim were cut in with the spray on the side of the building where the spray test was made. On the second coat, however, the cornices were cut in by hand with a brush, in order to assure a neat job. The time of the brush work was counted in as spray-gun time.

It has previously been assumed that the average journeyman painter, working on wall surfaces and using a hand paint-brush would do about 200 square feet an hour, or about 250 square feet an hour on roof work. In these tests however a much greater speed was attained in the hand-brush work. It is assumed that this was due to the great interest of the painters in the test.

Observation of the completed work showed that practically no difference in the appearance of the spray and the hand-brush work existed, with the exception that the spray work was slightly more opaque. The painters in applying the paint by hand with 4½-inch brushes used drop cloths at the base of their work, whereas no drop cloths were used by the spray workmen. There was apparently little paint falling to the ground, the only loss being in the form of a fine mist. On a damp day this mist, of course, would be greatly intensified due to the presence of the volatile constituents of the thinner. This mist would lead an observer to believe that considerable paint was being lost, whereas, as a matter of fact, only a very little quantity of paint was being dissipated as mist. The mist was of a somewhat colloidal character and the effect was largely optical. On the interior work, however, a noticeable difference was shown. The mist in the room where the paint was being applied by spray guns was very noticeable. Drop cloths were required on the floors in order to prevent staining. Painters employed for continuous periods on interior spray work might to advantage wear a simple form of respirator. The roof work was, of course, subjected to strong currents of air, but there was apparently no very large loss of paint. It was observed, however, that the overalls of the painters using the spray guns become somewhat more soiled than where hand-brush work was being done.

On the interior tests, one room was done by two painters with hand brushes and two rooms with the spray gun by one operator. The rooms faced a courtyard in which the machine was placed with hose leaders running up to the work. The ceilings of the rooms were arched, four arches meeting in the centre of each. This made the painting rather difficult by hand but very much easier for spray work. The side walls had four projecting columns, one at each corner, and between the tops of these columns and the arched ceilings there was a heavy scroll cornice. Each room also had a fireplace and chimney breast and large recessed combination windows. The hand work was somewhat marred by streaks and the covering was poor. The spray work was greatly superior. A very much heavier coating of paint was apparently applied. It was necessary to put on two coats of paint by the hand brush in some instances in order to get satisfactory covering.

Information gathered from some of the journeymen painters indicate that they are not averse to the use of the spray gun after they become acquainted with it. In fact, the painters showed less fatigue at night than when using hand brushes. Some were therefore enthusiastic about its use.

Dr. Gardner's paper was accompanied by tables of tests which are here omitted because of limitations of space. These tables show that on previously painted metal roof spraying requires approximately 10 *per cent more paint than brushing, while brushing requires approximately* 200 *per cent more labor than spraying.*

On previously painted brick walls and stone cornices spraying required approximately seven per cent more paint than brushing, while brushing required approximately 109 *per cent more labor than spraying.*

On combined ceilings and walls of plaster spraying required approximately 40 *per cent more paint than brushing but gave quite good hiding in one coat, while brushing required approximately* 160 *per cent more labor than spraying and gave poor hiding in one coat.*—Editor.

SPRAYING PAINT ON STEEL GIRDERS, ON A FRAME BUILDING AND ON A STUCCO WALL

The Menace of Vibration

Some Interesting Observations on Troubles in Turbo-Generators

By E. V. Amy, E. E.

THE recent rapid development of large capacity steam turbine-driven electric power-generating units has made the subject of vibration of great importance and worthy of more serious attention and consideration, for both the designer and the operator. Vibration has become a factor having considerable influence on the present limits of speed and capacity of single shaft steam turbines. The exact nature of the vibration set up in the wheels and blading of such turbines is at present one of the engineer's most difficult problems. Very little is known of the theoretical nature of this form of vibration although common to all steam turbines. It remains a problem requiring further investigation and research on the part of the engineer and designer.

It is not the purpose of the following article to enter into a theoretical discussion on the nature of this type of vibration, but, on the other hand an attempt is made to outline the many other causes of vibration in large turbo-generators of present-day design, and to mention some of the troubles and dangers which often arise when vibration in such machines becomes abnormal and is allowed to persist unremedied.

In the reciprocating engine with its low speed any lost motion or misalinement makes itself known as a knock or pound, while in the case of the turbine with its high speed and very delicate balancing the slightest knock or pound may become very serious vibration and cause considerable damage to the machine. With high-speed machines like turbines it is vitally essential that all revolving parts be accurately balanced, and that this condition of balance be maintained at all times during the operation of the machine. The proper balancing of machines is in fact a science in itself.

For the proper balancing of the rotors of steam turbines and generators, two balances are required to ensure a steady running condition, these are the static and the dynamic balances. The static balance is obtained by revolving the rotor by hand on a pair of knife edges or balancing stools. It is revolved and allowed to come to rest, the point at the bottom being the heavy part. Temporary weights are fixed to the rotor opposite this part and the rotor again revolved and weights added until it will stand or come to rest in any position. The rotors are balanced dynamically with as much care as possible on a special test floor by the manufacturer. The details of the apparatus employed by the various turbine manufacturers for dynamically balancing their machines varies of course in design, but in general the method is to rotate the body at operating speed by some external source of power, with the shaft and bearings spring held, so as to allow a slight oscillation of the shaft in one plane to be produced by any out-of-balance condition of the rotor. The shaft is chalked at each extremity and by gradually advancing a fine metal stylus until it lightly touches the revolving shaft at the high spots of the oscillation, a mark is thus made in the chalking on the shaft indicating the relative places where the balance should be changed. The weight is altered and the test repeated until the best balance is obtained for that end of the shaft, so that there is no oscillation. The other end is then balanced in the same manner and the dynamic balance of the rotor and shaft as a whole thus completed with respect to the journals in which the shaft is held.

Few large rotors are actually in a state of perfect balance owing to the difficulty in obtaining an absolutely accurate dynamic balance. Furthermore a physically perfect balance for all speeds is not attainable. The greater the speed at which the rotor is to be operated the more careful and accurate must be the dynamic balancing.

The intensity of the vibrational force due to out-of-balance of a rotor will in magnitude be proportional to the square of the speed and the number of times this force is applied per minute will vary directly with the speed of the machine. Therefore if we consider only the fatigue stress the harmful effect of a given amount of lack of balance will vary as the third power of the speed of rotation of the machine.

A dynamic balance considered perfectly good for a certain environment may prove to be a bad out-of-balance in other surroundings. A large capacity machine that runs quite smoothly on a massive foundation of concrete may set up dangerous vibration and noise when mounted on I-beams or set up on a steel structure. Commercial requirements call for the designing of standard types of machines, made in quantities to meet the demands of a general market. In many cases the refinement of balance depends upon the average place and conditions of use, as far as can reasonably be predetermined. However should such a machine happen to be installed under adverse conditions which resonate with any little out-of-balance which the machine may have, it is immediately blamed for the trouble and in many cases condemned; whereas it would have run perfectly well if a little more consideration had been given in slightly modifying the foundation.

For all bodies mounted on a shaft and rotated at high speeds about fixed axes there is a certain period at which vibration will become excessive, this is called the critical point of speed and is believed to be caused by a change in the axis of rotation due to the deflection or bending of the shaft which causes the rotor to revolve about a new axis termed the axis of rotation or deflection and which alters the center of gravity of the body and causes vibration. This may not occur at the highest speed, as sometimes this vibration decreases as the speed is increased.

Vibration in machines like steam turbo-driven generators may be due to causes internal or external to the machine, or both, the result being cumulative or otherwise. In general, however, the most common causes of vibration are unbalanced rotors, bent or poorly alined shafts, loose parts, improper foundations and fastenings, excessive speed, excessive and fluctuating loads, and vibration of the structure housing of the machine having its periodicity of vibration superposed upon that of the machine.

The most serious and dangerous kind of vibration in turbines, although not frequently encountered in well designed machines, is that due to revolving parts improperly coming in contact with the stationary parts; this applies especially to the buckets. Such trouble will lead to the greatest damage if not promptly detected and properly dealt with. A vital maxim in turbine practice is to avoid any internal rubbing.

One of the greatest troubles experienced in maintaining good balance of Turbo-generators is due to the shifting of the conductors. The slightest shifting of these conductors on the rotor of a large generator is likely to throw the machine considerably out of balance. This often happens after the generator has been in operation for some time; as the insulation dries and becomes compressed by centrifugal force on the conductor it allows the conductor to loosen a little in the rotor slot. Once these conductors become at all loose they may shift with load changes, causing deterioration of the insulation and failure under normal potential.

Vibration may be caused in a machine by allowing too much bearing clearance. Such vibration is more or less of a local nature, and while it may be felt throughout the entire machine it is usually more intense at the bearing or bearings which are loose. It is also more noticeable when the machine is running with light load than with full load, or in the case

of alternators when the field current is off, becoming less as the field magnetism grows stronger or the load becomes greater, holding the roter in a more fixed position. In some cases this vibration can be reduced by feeding more oil to the bearings.

The proper lubrication of large steam Turbo units is an important problem upon which the smooth operation and future life of the machine are greatly dependent. If the oil film under a bearing should break down due to a poor supply, low pressure, or other failure of the lubrication system, the bearing besides becoming heated would be let down with the possibility of causing serious damage to the blading of the turbine. Unequal wear on the bearings or shaft would in turn throw the machine out of alinement.

A serious trouble sometimes encountered in large Turbo-generators as a result of excessive vibration of the machine is that the emergency steam valve accidentally closes, shifting the generator's load to other machines. This may prove a very grave matter in power stations where the load is 30,000 kva. or more. A leaky throttle has often caused a turbine to vibrate when first started. Allowing steam to enter when the turbine is standing still heats the rotor casing unequally which causes the rotor to run out of true and vibrate when started. For this reason it is the general custom to rotate all large steam turbines slowly while warming up.

The failure or improper adjustment of labyrinth packing has in the past few years caused considerable trouble with many of the larger turbo-generators, often necessitating their shutting down when most needed in operation. The function of labyrinth packing is to reduce leakage losses. It is used in some form in all types of turbines. The essential idea on which the packing is based is not so much the causing of the steam to take a tortuous path as to wire-draw it at a great number of points. In most single flow turbines it forms the packing on the periphery of the balance piston which is used to counterbalance the thrust of the steam on the active turbine elements. In nearly all other types it is used in the steam glands to prevent the flow of steam through the opening in the turbine casing through which the shaft passes. Theoretically it should be durable enough to withstand the action of the steam but not strong enough to impose injurious local heating in case of rubbing or surface contact. In the past it was the practice of many manufacturers to make this material too strong and considerable trouble was caused by heating due to contact which resulted in distortion of the holding rings. Nowadays this packing is made of different design and better material which will not cause injury to adjacent parts in case of surface contact.

In general it might be said that there are many degrees and types of vibration in large steam turbine-driven units, causing as many effects, some obvious and others not so apparent. But in nearly all cases vibration sounds its own warning and therefore requires the constant vigilance of the operator and attendants. The operator and the attendant must be always on the alert and thoroughly familiar with all normal running conditions as to sound and vibration, so that he can promptly detect anything unusual in the operation of a particular machine and quickly diagnose the trouble, if any, and to report it or apply the proper remedy at once, before it becomes of such a nature as to cause damage to or wreck the machine.

MANGANESE.

In a report to the Bureau of Mine, W. C. Phalen describes several uses for manganese other than steel making. Estimates of the quantity of manganese ore used in the industries other than metallurgical vary from twenty-five to fifty thousand tons yearly. Most of the ore is a high grade of pyrolusite, commanding a much higher price than metallurgical ore, and is usually described as "chemical manganese ore."

The principal non-metallurgical use of manganese is as an oxidizing agent in the manufacture of dry cells; as a decolorizer in certain kinds of glass where it combines with the iron present in the sand to form a colorless or neutral shade of iron salt; and as a drier in oils, paints, and varnishes. A small quantity enters into the manufacture of manganese chemicals. In text-books the use of manganese as a raw material for the production of chlorine through the reaction of manganese dioxide with hydrochloric acid is given, but this is no longer a commercial operation. No doubt chlorine, which is produced when manganese chloride is prepared, may be used, but today chlorine gas is an abundant by-product in the electrolysis of brine in the manufacture of sodium hydroxide and potassium hydroxide.

It is interesting to note the part played by manganese dioxide in the dry cell which is ordinarily, but incorrectly, called a dry battery. A modern American dry cell of the usual type is a portable modification of the "disque Leclanché" cell invented by Leclanché about 1868. The negative pole consists of a cylindrical zinc can of which about seventy-five million are now made annually in the United States in the number six size alone. The can also serves the purpose of a container and the popular size, number ix, is about two and one-half inches in diameter by six inches high. The inner surface of the zinc is lined with a special grade of absorbent paper, acting as a reservoir for the electrolyte and as a diaphragm between the zinc and the positive pole. The depolarizing mass, called the mix, is tightly tamped into the can around a centrally located carbon electrode to within about one inch of the top. This mix is ground carbon, usually calcined petroleum coke, and graphite, manganese dioxide ore, and the electrolyte. The mix, together with the carbon electrode, forms the positive pole and after it has been tamped, the paper is turned down over it, sand or sawdust is poured in to a depth of about one-half inch, and the cell is sealed with a hot pitch composition. The layer of sand provides an expansion chamber for the electrolyte, ammonium chloride, and the excess gas, and also a dry bed for the hot pitch.

Comparatively little of the zinc is used up during the service life of the cell and one of the problems of the dry cell manufacturer is to so construct the cell as to obtain uniform corrosion. The paper must be porous enough to allow the electrolyte to diffuse through it but still retain the smallest particles of carbon and manganese.

Much work has been done on methods for recovering the unexpended manganese dioxide from these dry cells and at least one laboratory has reported substantial progress.

OIL IN ENGLAND.

The acute need for fuel in Great Britain has excited great interest in the possibility of disçovering deposits of petroleum. Much prospecting has been done, especially in Derbyshire. Whatever success may finally attend those investigations, there has recently been discovered a source of fuel oil which, if reports are true, promise to become of first importance and of immense value. This is the oil shale deposit of Norfolk.

In 1907 Dr. Forbes-Leslie began a systematic investigation of these deposits, which has resulted in the finding of large quantities of shale and the formation of a company for their development. At first little interest was taken in these shales as their sulphur content was too high to permit their use as a source of fuel oil. Further investigation has shown that this is true only of the upper seam of shale.

These Norfolk shales are entirely different, geologically, from the well known Scotch shales. They consist of a clay saturated with liquid petroleum from some source below. A form of ozokerite occurs with them. When retorted they yield 40 to 50 gallons per ton of an oil practically free from sulphur and rich in motor spirit and paraffin.

The quantity of shale available is practically inexhaustible, the amount being estimated as 2,000,000,000 tons. This amount is sufficient to supply England's present oil needs, as indicated by her imports, for over a century. The seams lie between the surface and a depth of 400 feet, average 150 feet in thickness and are remarkably uniform in thickness and yield.

U. S. ARMY MARTIN AERIAL TRANSPORT EQUIPPED TO CARRY PASSENGERS

The Airplane as a Commercial Possibility*

Changes Necessary in Present Equipment, and Future Developments

By D. W. Douglas

THE cessation of the great war has left the airplane machines and engines of the highest quality in the world. industry in America well equipped to design and produce It has, however, left it in poor shape for existence, for few of the airplanes developed for military purposes hold much promise of successful adaptation to peace-time commercial uses. Future military business of any magnitude is problematical. That the war has advanced the science of aeronautics and in a way that will help to solve even the commercial problems is true; and it has given the industry opportunities for the betterment of its products that would not have come to it in double the period of time in peace. That commercial use must be made of airplanes to support even a part of the capital and interests involved in the business at present, seems necessary.

Many people argue that the Government cannot afford to allow this great and new industry to languish because of lack of business, but must foster and further it by subsidy or continued military orders. That such a course would be welcome at this critical period is undeniable, but total dependence of existence on this problematic possibility would be fatal. Governments are sometimes slow in acting in a sufficiently decisive manner on such problems, as is witnessed by the disappearance of our merchant marine in the latter part of the nineteenth century. Furthermore, government subsidy does not always appear healthy for the sound development of commercial projects. Of the early transcontinental railroads, those that received the least or none of the support accorded by the Government remained the most financially sound.

The problem before us today is: What practical use can be made of airplanes, what volume of business can we expect to secure with them, what changes of or developments from present military machines will be necessary to give us an efficient commercial machine, and what does the future hold for this new means of transportation? Let us inquire into the probable fields that the commercial airplane can hope to enter, and, either competing successfully with other means of transportation or supplying the lack of such transportation, become a recognized factor in the development of commerce and the furtherance of social and economic intercourse throughout the world.

PASSENGER TRANSPORTATION.

Since speed is the most outstanding present-day advantage of the airplane, I rank passenger carrying first in importance. Many of our daily business and personal affairs can be successfully conducted only by a personal meeting or inspection. Correspondence, telephony and telegraphy cannot supply the complete satisfaction of actual personal contact. Where any great distance separates the subject and his objective, present-day express train service often proves too slow.

Time wasted in travel means money lost, suffering endured or pleasure sacrificed. Granted safety comparable with that of our present means of travel, in point of fatalities per miles traveled, and that I trust will be demonstrated soon, are there not many instances in the life of any person when he

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would gladly pay twice the railroad fare to reduce his travel time to one-half or one-third? Is it not conceivable, then, that having once found that this saving is worth something to him at a critical time, he will avail of it again for some less important reason? Soon he will find, if he be a man of large and pressing affairs, that he is remolding his schedules on the basis of this new time-annihilating service. The first problem, then, seems to be to win the confidence of the public, to institute a successful passenger transportation line between two great cities such as New York and Cleveland.

Aeronautical people all feel confident that with the lessons learned from military experience and with new safeguards thrown around the airplane in its operation and maintenance, such a service can be safely embarked on with our present-day knowledge and material. This must be proved by actual performance rather than by statement, and so the airplane builders or those with the necessary knowledge, enthusiasm, and capital who will come forth as commercial operators must take the risk. In one way or another they must actually carry passengers. They must carry them on schedule, comfortably and without mishap, and for a reasonable period of time. Experimental human material is needed, then, in addition to the experimental carriers of it. To my way of thinking, and from observation of and conversation with many people, there is plenty of such material in the adventurous, the curious and those whose extremity may be so great as to warrant the chance they are sure to believe they are taking at the time.

Granted, then, that sufficient patronage of a not too serious order can be counted on for starting a passenger-carrying airplane line of small size, what form will this first venture assume? Three methods of attack can be followed and are being followed at this time. They are:

(1) Scheduled regular service
(2) Special taxi service
(3) Tourist service

Of the three the first seems to hold the most promise of giving us our first real data on costs, maintenance and traffic. While it appears offhand to involve the risking of more capital than the last two, it need not preponderate greatly in this respect and certainly will offer a more accurate count of the public pulse than the other methods. By scheduled service I mean, of course, the operation of one or more machines flying between two or more points on a time schedule properly based on the safe speed of the plane, the altitude flown and the head winds likely to be encountered. No such service has as yet been actually started either here or abroad.

In England various airplane firms have ready machines carrying from 10 to 40 passengers; the French Farman carrying 12 persons and the big Caudron Company are only waiting for military questions to be settled before opening up regular service between London and Paris and other European cities. England has big projects along these lines throughout her colonial possessions and seems imbued with the determination to realize them. In Italy Caproni is building larger passenger planes than anyone, which it is said will be operated from the northern to the southern part of that country and even across the Mediterranean to the African possessions.

Other enthusiasts believe that the safest course to pursue in breaking into the transportation of passengers is through the use of the taxi system. To illustrate this I may state that the Curtiss Aeroplane Company intends to maintain a fleet of fast machines at a flying field near New York City, always in readiness with expert pilots in attendance to take anyone with the necessary confidence and money to any part of the United States. Our Air Service has for some time been using planes for a similar service. In Washington several machines and some of the best pilots in the service are ready at any time to carry high officers or officials on a joy ride or a quick official trip to other cities within 400 miles.

At Atlantic City companies are planning to handle the tourist trade. That they will meet with success in joyriding pleasure seekers next summer seems dependent only on their intelligent use of the best materials and personnel.

AIRPLANES AS MAIL CARRIERS.

Passing to the second commercial use of airplanes, mail carrying, we enter a field where the element of danger is not of so much importance. It is not to be neglected any more than in passenger carrying, but the possibility of crashes do not limit the initial business.

Under the heading of mail carrying I will group several functions:

(1) Regular mail transportation
  (*a*) By the government
  (*b*) For the government
(2) Fast dispatch service
(3) Financial service

In regard to the carrying of mail by plane, everyone is acquainted with the fact that the Postoffice Department has had a service in operation for the past year between New York City and Washington. It has operated this with its own personnel and material, and made a remarkable record on this run for efficient and continuous service. The amount of mail carried has, of course, been small as the service is only a beginning. About 160 pounds of mail is carried every day from each city, the pilots flying in all sorts of hazardous weather. Rain and storms fail to frighten them, and the instances of failures have been very few. The Chicago-New York City route was, as you know, unsuccessful in the first trials, but this was due mainly to faulty machines for this long haul, ignorance on the part of the pilots of the country traversed and a rather hasty start without proper organization and equipment. Next spring this run will again be instituted, and judging from the preparations being made and the machines that will then be available it should be as successful as the aerial postal service operating between New York City and Washington.

Whether the Postoffice Department will contract with airplane transportation companies for carrying mail in other localities will depend to a great extent, I judge, on the record of performance actually accomplished in operating their lines for some other uses. It is not inconceivable that a company which had been regularly and successfully carrying passengers on a certain route would be able to secure contracts to carry some government mail along with the regular load.

Under the second function of mail-carrying types of planes comes independent carriage of special commercial dispatches. A service could be maintained with fast planes, flying both night and day, that would bid fair to outrival the night telegram service between cities over 300 miles apart. It would be as quick at probably lower charges and have the great advantage of accurate transmittal and the possibility of conveying information other than that written.

Machines engaged in this work could also handle the third class of mail-machine operation. Where the saving of a few hours in the time of transmittal of a draft on a bank in one town, to be deposited in the other, may mean the saving of a day's interest, fast airplane service would certainly be an advantage.

GENERAL EXPRESS TRANSPORTATION.

If we now take up the third peace-time use of the heavier-than-air machine, general express transportation, we enter a field which at first glance does not appear to offer much encouragement to the airplane as a carrier. Express and fast freight service throughout developed parts of the world is generally good and, of course, much cheaper than similar service by wing. On the other hand, as in carrying passengers, the future promises a class of people to whom the greater speed is a worthy consideration; so in the transportation of merchandise we will find classes of goods which can bear the extra cost of moving in exchange for the time saved. This may prove particularly true in conveying goods from small

towns with indifferent rail service to the larger centers. Among the articles which can bear the extra tariff are:

(1) Perishable goods
(2) Replacement parts for damaged machinery
(3) Medical and surgical materials
(4) Motion picture films
(5) Newspapers
(6) Luxury articles

Taking up the question of perishable goods that can bear the expense of airplane travel, we may list such things as high-grade certified infants' milk, rare and out of season fruits, vegetables and flowers. The milk for New York City is supplied largely from upstate dairies not having the fastest of rail service. With a preliminary cooling at the dairy this milk could be carried quickly and deposited still cold in the city. Where the breakage of intricate machine parts threatens the tying up of a plant, the aerial express line should find an opportunity to be of value. Shortages in factories working on a production basis that could ill afford an interruption could be made up from stock in a distant town in the minimum time possible through the air. Occasions arise in epidemics or catastrophes where the shortage of medical and surgical materials, personnel and food becomes serious. With airplanes such supplies could be rushed in the fastest way. Motion picture films could not only be distributed in the shortest time by airplanes, and thus cut down exchange and idle time, but the service would add to the advertising campaign of film companies. News grows stale quickly and small-town papers do not always satisfy the residents of such communities. The faster distribution would increase the out-of-town sales of the daily papers of our large cities and widen the range of their circulation. Articles of luxury which bring high prices in proportion to their weight could in many cases have quicker distribution profitably. Advertisement would enter here to a greater extent than in any other class of service possible. Confectioners and florists in the large cities, enjoying a wide reputation and a high-class trade, could broaden the field of their patronage considerably.

AERIAL TRANSPORTATION OF MINERAL ORES.

Mineral ore, while appearing to be a difficult cargo for seemingly flimsy aircraft to carry, is, in certain localities and in certain grades of ore, a practical load for airplanes. Where mines producing rich ore are located in inaccessible country not tapped by railroads or highways, barring exceptions where the character of the terrain precludes the possibility of landing fields or where altitudes are excessive, an aerial transportation system could be installed without the necessity for heavy investments in roadbeds and grading and could be operated at costs that would not be excessive. If the mine be a small one, removed from the possibility of surface service, the airplane can take out the ore and when the workings are barren leave no great amount of useless investment on the location. In addition to carrying the ore out, labor, equipment and supplies can be brought back on the return trip. Where speed in the operation of a newly found mine and in the marketing of its ore is an advantage, because of high market prices, an aerial system could be put into operation much faster than any surface system and would be delivering the ore months before the road or grading work could be finished.

The transportation of the ore from the mines to the nearest railroad might not be found to be the limit of this service, for at times and in certain undeveloped localities it might pay to carry the load farther to a district of better rail service. The distance of handling might today be limited to 300 or 400 miles because of the poor economy of carrying too much fuel, but there is reason to believe that with great load capacity and machines developed for this class of service, this range could be increased without too much loss in economy to 500 miles. To obviate the necessity of landing with a great load of ore, the machines could fly low over the receiving yard and drop their burden from the air. Where the haul was short, several round trips from the mine to the depot might be made with no landings at the latter, and time and the wear-and-tear incident to landing could thus be saved.

AERIAL PHOTOGRAPHY AND MAP MAKING.

One of the uses of aircraft that the war has done the most to develop to its present high state of accuracy is aerial photography and its application to the making of mosaic maps. Developed from the necessity of gaining accurate information as to the location and nature of enemy gun emplacements, fortifications and supply lines, the science of aerial photography has become such an exact one that not only can it be used to get true topographic maps, but it can be applied in the making or checking of maps and mapping observations. The bulk of this work, and all interested in the furthering of flying throughout the country are hoping that much of it will be done, will probably be diected by the Government through its military or civilian personnel. It is not inconceivable, however, that companies engaged in the publishing of maps of the various parts of the country, such as Rand, McNally & Co., could find a market for better maps based on aerial photographs.

Owners of great ranches and plantations might find it of value to have the added insight of their possessions and the correlation of their various sections that would be afforded by a complete mosaic map. Advertising literature and descriptive maps of cities, resorts and real estate developments made by the aid of actual aerial photographs would undoubtedly possess enough value to warrant the expenditure necessary to compile them. In surveying undeveloped country for laying new railroad lines through it, the airplane would not only be a valuable adjunct in transporting the surveying parties and supplying them with necessities, but would aid in the making of their contour maps.

OTHER MISCELLANEOUS USES.

Among the miscellaneous uses that we may hope to put airplanes to, come those of supervision and exploration. While in many of its aspects this work would dovetail with the photography previously outlined, in other ways it presents new fields. Consideration is being given today by the Government to the patroling of the great National Forest reserves by airplanes driven by or carrying an expert forest ranger. A greater check on forest fires could be exerted by this means and in that way much natural wealth conserved. More ground could be covered with smaller personnel, and reports of fires by wireless from the air to a central receiving station would expedite the rushing of fighting crews to the scene of the impending catastrophe.

The inspection and supervision of large properties is made more efficient and rapid by the employment of an airplane by the manager. It is reported that J. P. Morgan has bought a plane and engaged a pilot to aid the manager of some of his large wheat lands in keeping in touch with his work. Policing operations, both state and municipal could be aided by airplane squads. State constabulary could throw a force of men into an isolated town where a strike or riot impended, by the use of large fast machines kept at central flying grounds. In the exploration of undeveloped country for following waterways or determining suitable waterpower developments, airplanes would provide vision and perspective to the pioneers.

USE OF AIRPLANES FOR SPORT.

Among the last and what has appealed to so many as the first and best use to make of our present aircraft is the sporting development. Undeniably there is a field here, and had the war not intervened it would be further advanced. For customers the producers of sporting types of airplane will surely have many of the returned and discharged military aviators. Most of them would probably enjoy the possession and use of a fast, able little craft, but unfortunately an airplane will always be more expensive than a motor car and

hence few but the wealthy will be able to indulge their fancy.

One of the first obstacles to pleasure flying is the fact that suitable flying fields are not numerous or located in respect to each other in such a way as to make possible an ordinary jaunt of an afternoon. Flying in the vicinity of a field soon becomes tiresome. One way out of this difficulty is through the use of machines of the flying-boat type. Coastal waters, inland lakes and rivers provide ample landing room for sportsmen. Sport flying will not doubt increase in popularity in spite of its cost and probably be fostered by the Government. The enlargement of the landing facilities provided by the mail routes and commercial lines will assist. That it will ever approach the magnitude and popularity of motoring seems improbable; skill in flying is not possible of attainment by everyone; the hazards of flying can be combatted only by the employment of elaborate precautions beyond the means of individual fliers.

CHANGES IN PRESENT EQUIPMENT.

Having covered in general the uses of aircraft, we approach now the subject of the initial developments that are necessary before entering the field of commercial endeavor. These in the order of their importance are:

(1) Engines
(2) Airplanes
(3) Means of navigation
(4) Landing grounds
(5) Legal questions

As I expect to cover the future developments later, I will confine myself here to a summary of what changes, if any, we must make in our present equipment and methods.

Our best engines at present, as exemplified by the Liberty Twelve, seem to give promise, if properly handled and not overtaxed in power or length of service without overhauling, of giving satisfaction in regular service.

Our airplanes, of course, need considerable reworking to fit them for carrying passengers or inert cargoes, except possibly in the case of smaller machines used for special service. Some of our planes, built to give the ultimate in performance from a military standpoint, possess unpleasant features when applied to peace-time uses. These planes will be worthless as far as everyday use is concerned. Others will require only a changing of interior arrangements. Bomb compartments will be replaced by comfortably appointed cabins or conveniently arranged cargo holds. Accessibility and ease of replacement of wearing parts will be given prime consideration in redesigning these machines.

Our navigation means probably call for the most immediate developments. Air compasses now in use are not thoroughly satisfactory at all times and in all weather. Radio direction-finders have been developed and seem to promise a more accurate and dependable method of keeping a true course in flying across country above the clouds or in a rain or fog. Better maps are necessary at once. Present-day maps are usually lacking in true accentuation of natural landmarks such as rivers and mountains. Confusion is caused by the omission of some marks and the inclusion of others when perhaps both look to be of the same magnitude when observed from an altitude of 10,000 feet or more. Cities flown over should be marked in some way to be readily recognizable by night or day.

Means of signaling the location of a field are necessary in a fog. Since most fogs are close to the earth, captive balloons riding above the fog in daytime, or star lights shot above the fog at night, will make it possible for the aviator to find his field. Proper and adequate means of lighting fields for night flying are advisable, since in some kinds of service this will present advantages over day flying.

Radio lighthouses along established routes sending out distinctive signals at regular intervals will aid the pilot in checking his position, whch may be rendered uncertain by unknown wind conditions and loss of visability of the ground. Landing fields should be provided at reasonable intervals along the course of aerial routes. An endeavor should be made to locate suitable fields as near to town as possible in all cities contemplating airplane service, as a field distant from the center of a town tends to offset the time-saving of aerial travel. The shorter the run the more will be the magnitude of the disadvantage.

Serious contemplation should be given by the proper representative bodies of the State and the Federal Governments to the legal aspect of aerial transportation. Uniform laws governing the behavior of machines in the air and when alighting are needed, as well as inspection regulations to safeguard the public and eliminate ignorant and foolhardy operators. Proper instruction and examination of pilots are necessary; while the examination should not be so exacting at this time as to be unjust, it should be and can be thorough enough to safeguard against unsuitable and incapable operators.

FUTURE DEVELOPMENTS IN AIRPLANES.

It seems safe to assume that the uses of aircraft will expand rather than contract. This would indicate that we shall always have as many different sizes of machine and engine as now. Small single-engine planes will continue to attract sportsmen, will be used in special service and even in mail or passenger lines between small towns. Multiple-engine machines, however, possessing, as they do today, the added safety of being able to continue flight when one engine stops, seem certain to come more into use for all regular systems requiring the maximum of safety and dependence. Even though engines develop considerably in reliability, as they must and will, this type of airplane seems bound to predominate from other considerations. The size of the multi-engine machine will therefore probably vary more than at present. Starting with small two-passenger twin-engine airplanes, we shall probably have two, three, four and five-engine planes with horse-powers up to 5,000 and useful loads up to 20 tons, operating in different services in the near future.

As to the speeds that we may expect the machines of the future to attain, it appears that while more efficient machines and engines will undoubtedly increase the maximum possible, many types will be slow. Where a service is operated over country not possessing fast surface transportation, or over broken country and large bodies of water, the slower plane, say that having a maximum speed of about 80 m.p.h., will be the most economical. The attainment of higher speeds will always mean the lowering of the useful load carried. Where there is good rail service, or other conditions call for the maximum speed, we may expect to find planes in operation making with their full load anywhere from 150 to 200 m.p.h. Speed does not mean less dependence or safety but more often surer and safer service. It does, however, except in certain instances, spell higher costs per pound of load carried.

The tendency in engines, as far as their size is concerned, seems still to be toward greater power. What the limit will be is hard to predict, since it is restrained somewhat by developments in other directions. Unless radical changes in the methods now used in the making of air propellers occur, it does not seem that units larger than 1,000 h-p. will be practical. Two or more propellers driven from one powerplant by shafting or other means may, however, make it possible to double or treble this figure, lacking any developments in air screw construction.

As to new developments in airplane design, aside from larger or faster machines, it is difficult to see that this will follow any new or startling lines. The problem of descending and arising vertically with heavier-than-air craft, while probably not impossible of solution, seems to present insuperable difficulties. Very likely compromises will be effected which will permit airplanes to land in more restricted fields and in terrain of a rougher character than is now advisable. Lifting screws, air brakes, variable camber, variable area and better landing gears may be used in the solution of this problem.

Refinements of structures by more careful design or employment of better materials will undoubtedly continue and

will, by decrease of weight and head resistance, give greater speed ranges or greater load capacities.

Developments in engines seem to point toward the maintenance of power with increase in altitude and the consequent increase of speed and miles per gallon of fuel. Some success along this line has been attained already, and practical solutions appear to be forthcoming soon. More reliability in engines and the possibility of longer running without overhauling are of such advantage in commercial work that efforts will surely be bent in this direction. Better fuel economy will be sought not only from the fact that costs will be cut in this way but because weight will be saved by the reduction in the amount of fuel carried and the space gained will be available for more cargo or more comfort for the passengers. The three main developments in the engines then would seem to point to a higher weight per brake horse-power at sea level, but, of course, the maintenance of power at great altitudes and the lowering of the fuel consumption should offset this and perhaps eventually put us ahead of the present low-weight engine unit.

In the development of accessories and safeguards the field is broad and offers many opportunities. Automatic controls for the relief of the pilot seem certain of early attainment. Safeguards against fire and leakage from fuel tanks are well developed now, although not always applied. Improvement in both as to effectiveness and weight can be expected.

Muffling of engines, heating and ventilating of the cabins and housing-in of operators without restricting their vision will all come shortly and add to the efficiency of the pilot by reason of the increased comfort and freedom.

More durable materials for the covering of wings and bodies, protective coatings and the like will lower the present high rate of deterioration.

SERVICE COST DATA.

No doubt you have all at one time or another thought that you might like to take a trip in a passenger-carrying machine. You have no doubt wondered what the initial costs would be and what the rate per passenger-mile can be expected to be in the near future. With this thought in mind I have prepared the following brief cost calculations on a problematic service between Cleveland and Detroit. The costs include all operating and overhead expenses of a complete operating company. For this service I have assumed the use of one of the Glenn Martin Co.'s twin-Liberty, 10-passenger planes equipped with pontoons for water landing. I have done this rather than use the land machine as in both Cleveland and Detroit suitable landing fields are too far from the center of town. Also, with a water machine no hesitation would be felt in taking a straight course from the one town to the other. If a land machine were used, prudence would dictate the following of the shoreline, with the increased distance thus made necessary, combating the time saving of the service. It should be understood, however, that this particular service is not the best example as to economy or locational advantage. Moreover, costs over the water will be higher than over land because of the poorer efficiency of water machines. That the estimates shown can be bettered for more advantageous service is possible of proof.

CONDITION OF FLIGHT.

The distance is assumed to be 100 miles.

The high speed of the plane full out will be 105 m.p.h.

Regular flying will always be conducted at a reduced speed of the machine and the engines. This speed will average about 95 m.p.h. when each engine is delivering about 310 h.-p.

Schedule flying time will be based on this throttled speed, less 15 m.p.h. Scheduled speed will then be 80 m.p.h. and schedule time for the trip 1¼ hours. Schedules can be maintained against head winds up to 25 m.p.h., by running full out. As winds above this speed are occasional and usually accompanied by bad weather for flying, schedule time should be maintained on over 90 per cent of the flying days.

In figuring the costs of operation and the depreciation of the machines and engines, this schedule time of 1¼ hours per trip will be used, although the majority of runs will be made in less time than this. This will provide a factor of safety and cover idling of machines on the water.

We will assume that flights will be made 170 days out of the year, or about 75 per cent of the time. Further, we will consider that our average load will be eight people, or 80 per cent of the maximum.

The gasoline consumption will run 26 gallons per hour per engine or a total consumption per machine of 52 gallons per hour. The total oil consumption should not exceed 2 gallons per hour.

SERVICE.

Assuming that the amount of traffic will permit the operation of two machines, each making six trips a day, three machines a year will enable this service to be maintained, as this would allow each machine a yearly flying life of 100 days, with 90 days for repair out of the 270 flying days in the year. We will assume that the total life of the machine is 1350 flying hours, and that to keep it in the air this time 15 per cent of the original cost is expended in replacement parts. Labor and material for fabricating other parts will be figured also.

We will assume that to keep each machine in the air 1350 hours two sets of engines will be used and junked. The total running life of each engine would then be 675 hours. We will assume that in the life of each engine it is completely overhauled six times and that at each overhauling replacement parts equal in value to 10 per cent of its cost are used in addition to other labor and material for repairs.

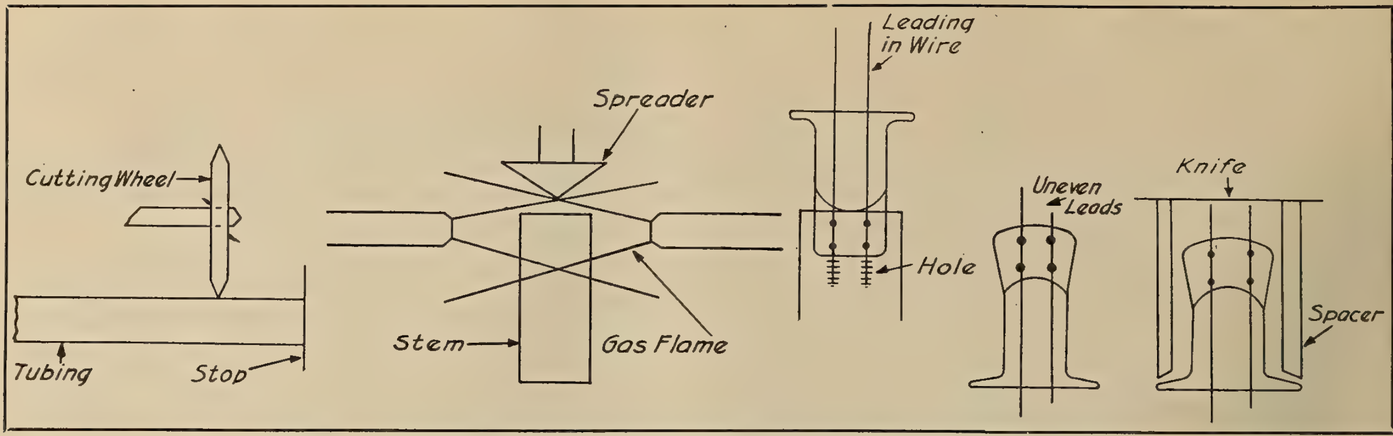
TIME SCHEDULE

	Leave Cleveland	Arrive Detroit	Leave Detroit	Arrive Cleveland
Machine No. 1 Pilot.......A	7.00a.m.	1 8.15a.m. A	2 7.00a.m. B	2 8.15a.m. B
Machine No. 2 Pilot.......B	9.00a.m.	2 10.15a.m. B	1 9.00a.m. A	1 10.15a.m. A
Machine No. 1 Pilot.......A	11.00a.m.	1 12.15p.m. A	2 11.00a.m. B	2 12.15p.m. B
Machine No. 2 Pilot.......C	1.00p.m.	2 2.15p.m. C	1 1.00p.m. D	1 2.15p.m. D
Machine No. 1 Pilot.......D	3.00p.m.	1 4.15p.m. D	2 3.00p.m. C	2 4.15p.m. C
Machine No. 2 Pilot.......C	5.00p.m.	2 6.15p.m. C	1 5.00p.m. D	1 6.15p.m. D

It is seen then that four pilots are operating every day, each making three flights totaling 3¾ hours in the air. Six pilots will be required to give the proper relief and reserve.

Here follows a detailed statement of capital invested and expenses, which is omitted. The estimated cost per passenger mile is $0.18, total investment, $349,800 and percentage of profit on investment 30.—Editor.

Assuming larger and faster land machines working up to the limit of their capacity, it can be shown that passengers can be carried at a good profit as low as 10 cents per passenger-mile. The fuel consumption mentioned is a little high because the engines are throttled and the Liberty burns 33 gallons per hour full out, developing 400 h.p. Throttling down to 310 h.p., the engine speed is approximately 1600 r.p.m. We have no accurate results on gasoline consumption at that speed, but I know that going to Washington we burned a little more than 26 gallons per hour per engine at about 1600 r.p.m. I think that consumption could be reduced.



FIGS. 1 TO 5. FIRST STAGES IN THE MANUFACTURE OF HEADLIGHT LAMPS

1. Cutting tubing for the lamp stems with an emery wheel. 2. Flaring end of tubing for junction with bulb after assembly of filament. 3. Method of inserting leading-in wires. 4. Uneven lengths of leading-in wires—often a result of cutting leading-in wires to exactly the required length. 5. Leads of uniform length insured by trimming after sealing in.

Improving the Automobile Headlight Lamp*

Details of Manufacture and Testing

By L. C. Porter

LAMPS that are intended for use with lens systems or parabolic reflectors must have the light source located along the axis, usually at the focal point, and it is readily seen that the manufacturing methods must be adopted which will insure uniform dimensions in lamps of a given type, as only with such lamps can replacements be made quickly and satisfactorily. The following article describes the manufacture of automobile headlight lamps stage by stage, indicating that every effort has been made to secure a product as nearly uniform in dimensions and performance as is possible.

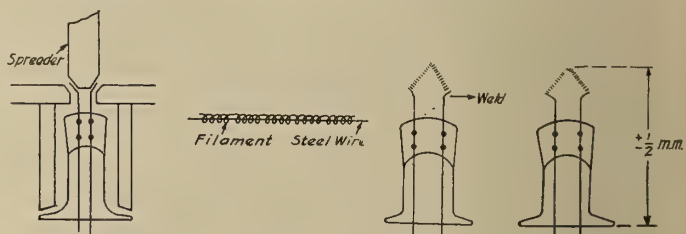
During the war the greatest need in the manufacture of headlights was quantity production with minimum labor and time. Now, however, the pressing need for minimum labor is past and more attention can be given to perfecting the quality, and uniformity of product is one of the things that is being given special attention. Since the armistice was signed an engineer has been appointed to study the manufacturing methods and suggest changes which will result in more perfect automobile headlight lamps. He has instituted a system of gages and inspections which is proving remarkably effective. It may be interesting to describe in detail the present method of manufacturing a typical lamp, say the 6-8-volt, G-12 bulb, 21-c-p Mazda headlight lamp and to point out recent improvements and call attention to the inherent variations required for practical manufacturing in large quantities.

The stem of the lamp is made from straight glass tubing received in long pieces. This tubing is gaged for thickness and diameter. It is then cut up into short pieces of the proper length for the stem, by pushing the end of the tube against a stop and then moving it to a rapidly revolving emery wheel, see Fig. 1.

The next operation is to put these short tubes into an automatic flare machine, which heats one end of the tube by means of a Bunsen flame and then spreads it out with a rotating metal plunger (see Fig. 2). Until recently this flaring was done by hand, resulting in a considerable variation in the spread of the flare and consequently in the length of the stem. With the automatic machine, however, the plunger enters a certain fixed distance and, being of constant diameter, there is less chance for variation in length. In order, however, to see that everything is working properly a certain percentage of all stems are gaged for length and the result of these tests are recorded.

*Reprinted from the *General Electric Review*, January, 1920.

The next operation is the insertion of the leading-in wires (see Fig. 3) in the stem. The glass tube is placed in a machine, flare end up, and the two wires stuck down into holes in the rod holding the glass. Occasionally one of these wires will be slightly bent, or a particle of dirt will get into one of the holes, thus preventing the wire from going in its full depth. After the wires are in place the glass is rotated and heated by Bunsen flames until soft and then the glass is pinched together to make the seal. Formerly the leading-in wires were cut to just the required length and when it happned that a wire did not go to the very bottom of the hole, the result was leads of uneven length on the mount (see Fig. 4). Now, however, all leads are made two millimeters longer than necessary, and after being sealed in the stem



FIGS. 6 TO 9. FURTHER STAGES OF MANUFACTURE

6. Leading-in wires being shaped ready for attachment to filament. 7. Forming filaments by winding on fine steel wire. 8. Shape and position of filament after being electrically welded to leading-in wires. 9. Permissible limits of variation in assembly of lamps.

are trimmed off by a semi-automatic machine which fixes the distance from the top of the flare to the ends of the leading-in wires (see Fig. 5) and assures leads of uniform length. This means a considerable waste of nickel, but the high cost thus entailed is warranted by the more uniform product obtained.

The next process is to bend the leading-in wires preparatory to welding on the filament. This used to be done by hand, but is now accomplished semi-automatically by a metal plunger, the stem being held against the top of the flare to keep the overall length constant (see Fig. 6). The stem is now ready for the filament, which is made as follows:

The lamp under consideration being a 6-8-volt, 2½-ampere lamp, it will be gas-filled and will require a coiled filament. To make this the tungsten wire is automatically wound around a fine steel wire. The winding machine makes a constant

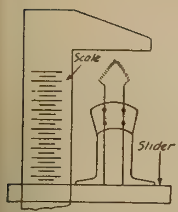


FIG. 10. METHOD OF GAGING OVER-ALL ASSEMBLY LENGTH

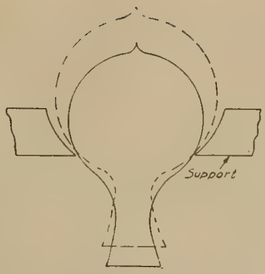


FIG. 11. HEIGHT OF BULB IN MACHINE VARIES WITH DIAMETER

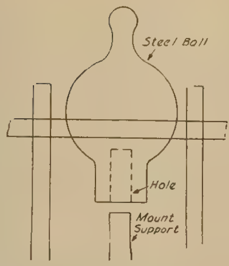


FIG. 12. MEANS FOR MOUNTING FILAMENTS IN CENTER OF BULB

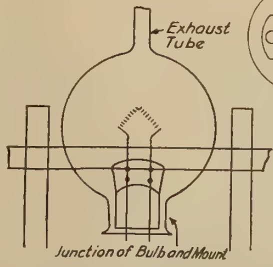


FIG. 13. BULB IN POSITION READY FOR MELTING TOGETHER

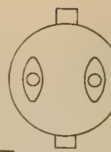


FIG. 14. LAMP BASE, POSITION OF LEADS AND PIN

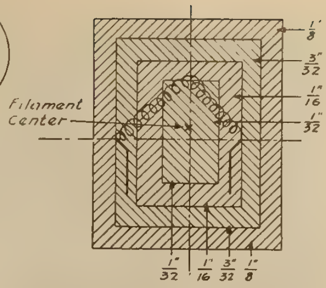


FIG. 15. CHART FOR DETERMINING POSITION OF LIGHT CENTER

number of turns, then allows the coil to pass along, leaving a short piece of straight wire before making another coil. The result is a series of connnected coils wound on a steel wire, as shown in Fig. 7.

These coils are then cut apart with a pair of pliers, this work being done by hand and there must necessarily be some slight variation in the length of straight wire beyond the coil, though a standard of two millimeters has been set. These little coils are next bent by hand into a V shape, the operator picking out, as nearly as practical, the center of the coil as the bending point.

The filament coils are then put into a hot acid bath which dissolves out the steel core on which they are wound. The filaments are then heat treated at 1000° C. in hydrogen gas, which removes all impurities and leaves them ready for mounting.

The filament is now laid on the leading-in wires and is semi-automatically electrically welded to them (see Fig. 8). In this process it can be seen that there must necessarily be some slight variation in the length depending on the angle at which the filament is bent and the exact position in which it is laid on the leading-in wires. The variation in overall length of the amount which has been set to take care of these conditions is plus or minus one-half millimeter measured from the bottom of the flare to the point of the filament (see Fig. 9). This is gaged by a sliding rule (see Fig. 10), the mount being placed on the slide and brought up until the point of the filament touches the upper stop. The mount is now ready for sealing in the bulb.

The bulb is blown in a mold, but, strange as it may seem, the diameter of the bulbs will vary somewhat. In the mounting machine the bulb is held in a ring and the height of the bulb will vary slightly with its diameter (see Fig. 11).

In order to set the bulb properly a steel ball, of the exact size of a correct bulb, is made with a hole in it which allows the rod that holds the mount to rise exactly the right distance to bring the filament center in the center of the bulb (see Fig. 12). This device is used in setting the machine. The mount is then put on the rod and the bulb placed down over it (see Fig. 13). The bottom of the bulb and the flare of the stem are then melted together by rotating them in a Bunsen flame. After this is done it is necessary to "work" the glass at the joint a little to prevent cracking. This used to be done by removing the bulb and mount while still hot and drawing the latter down a little by hand, thus stretching the glass. Now, however, it is done by blowing compressed air in through the exhaust tube and stretching the joint by expanding it. There must necessarily be some

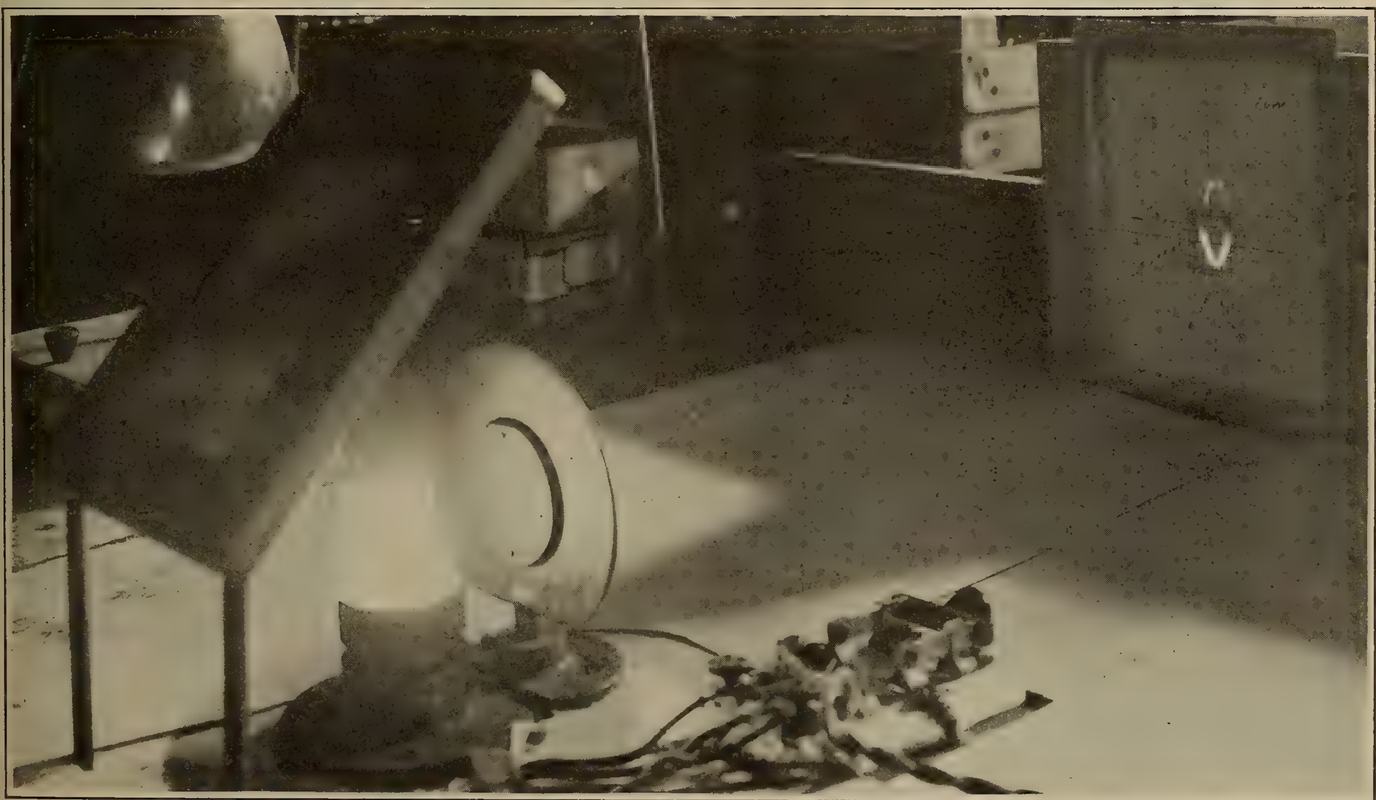


FIG. 16. OPTICAL DEVICE FOR TESTING LIGHT CENTER LENGTH OF LAMPS

FIG. 17. TEST FOR VARIATION IN LIGHT CENTER LENGTH

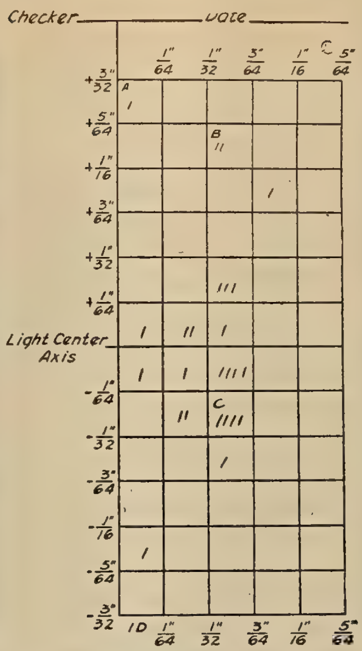


FIG. 18. RECORD OF A LIGHT CENTER TEST

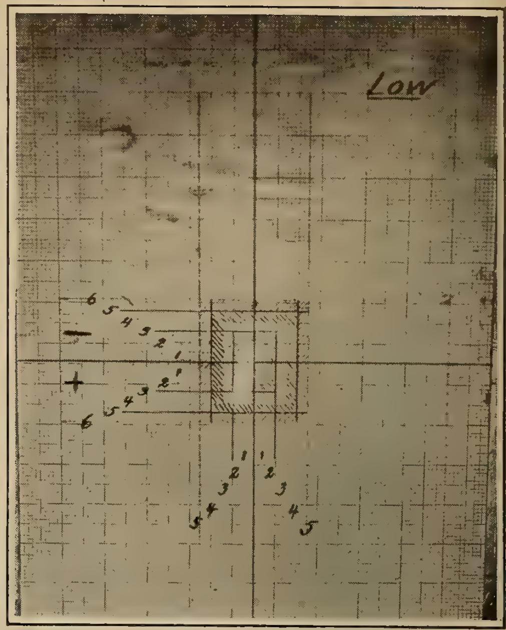


FIG. 19. TEST FOR VARIATION OF FILAMENT FROM AXIS

variation in length in that process and also the shape of the neck of the bulb will vary somewhat. The bulb and the mount are now ready for the base.

The two leading-in wires from the stem are stuck through the holes in the bottom. These holes are at 90 deg. from the pins on the base and thus determine the plane of the filament (see Fig. 14). The base is filled with glue and set into a heater to harden the glue. In this process if the wires happen to be slightly bent or twisted, the plane of the filament will vary somewhat from 90° from the pins, and even if the operator twists it around to 90° the wires are liable to cause it to spring back before the glue hardens. There must, therefore, be some leeway allowed in this respect. The slight change in shape of the neck determines to some extent the distance that the base will go up on the bulb before striking the glass.

It is easy, therefore, to see that with conditions as pointed out it is practically impossible to keep the light center length of the filament (distance between the nearer edge of the pins on the base and the center of the filament) to an absolute figure. The allowable tolerance in the light center length is 3/32 in.; *i. e.*, if the center of the filament is not more than 3/32 of an inch above nor more than 3/32 of an inch below the 1¼-in. distance from the top of the pins, it is acceptable. The filament must also lie entirely within 5/64 in. of the axis of the lamp passing through the center of the base and the tip. A certain percentage of every run of lamps is tested for these variations.

The device for testing the light center length consists of an optical projector which throws an image of the filament on a calibrated screen, see Figs. 16, 17 and 19. From this it can be easily determined just where the center of the filament comes. The center of the filament is taken as the central point of the triangle formed by the two filament legs and a line joining the points where they are welded to the leading-in wires. The testing device enables the lamp to be rotated 90° so that the filament image can be inspected as to its axial position.

In recording the test of a batch of lamps the form shown in Fig. 18 is used, which shows that of 26 lamps tested, one had a light center length of 1 11/32 in. (1¼ in. 3/32 in.) with some part of its filament 1/64 in. off from the axis (Square A); two had light center lengths of 1 5/16 in. with some part of the filament 3/64 in. off the axis (Square B): four had light center lengths of 1 7/32 in. (1¼ in. 1/32 in.) with some part of the filament 3/64 in. off of the axis (Square C) and one lamp had its filament outside of the light center length limit of 3/32 (Square D), etc.

Records are kept of all the tests and inspections during the entire process of manufacture and these are plotted as curves so that the engineer in charge can see at a glance just how the production is running and whether the various parts of the lamps are becoming more or less uniform.

The lamps which do not come within the specifications are opened and the defect corrected where possible. In cases where this is not practical the lamp is destroyed.

MAKING OLD BOLTS AND NUTS FIT FOR RE-USE.

It has always been the object of German railway management to reduce the cost of upkeep, but in the present conditions it is more essential than ever before.

The article is specially concerned with damaged bolts and nuts from the permanent way—these formerly went direct to the scrap heap. The methods for preventing this waste, which have been devised by Mr. Gerz, of Witten, deserve publicity. Bolts in which the thread had become worn were straightened, the defective part cut off, and re-threaded, thus making a perfect bolt of shorter length. The nuts, when rusted on, were cut off, heated in a furnace to loosen them on the bolt, and then re-tapped. In some cases nuts and bolts can be heated in a gas furnace, so that when hot they can easily be separated. Several photographs show the various types of bolts and nuts which were again rendered fit for use. These combined processes have saved the railway management very large sums.—Fabian, *Zeitung des Vereins Deutscher Eisenbahnverwaltungen*, Dec. 31, 1919. Abstracted by the *Technical Review*.

A NEW VEGETABLE IVORY.

A RECENT number of the French Bulletin of the Colonial Office gives a description of a new form of vegetable ivory, which can be used in European industry in place of the coroso. This new substance is produced by the kernel of an edible fruit growing upon a palm of the upper Senegal-Niger territory, the *Borassus ethiapicum.* The kernel is 7 or 8 cm. long and 5 cm. broad, thus permitting the cutting of balls or plates of considerable size to be used in marquetry, or the making of dominoes, piano keys, buttons, etc. The kernel becomes extremely hard when thoroughly dried; as a proof of this it is stated that it is at the present moment being used as building stones for the making of the houses of native chiefs, while it is expected that the future cathedral to be built at Dakar will have tinted pillars constructed of these kernels.

Automobile Headlighting Regulation*

Experiments to Determine How Present Laws May Be Improved

By Clayton H. Sharp and W. F. Little, Electrical Testing Laboratories, New York

THE subject of automobile headlighting regulation is one which interests us all from at least two standpoints. We are interested from the engineering standpoint inasmuch as we have a problem in illuminating engineering to deal with. We are also interested in it from the point of view of the public; that is, as users of the highway both on foot and in motor cars.

In the days when the headlighting of automobiles was done by acetylene gas, the headlighting problem was not what it is today. Acetylene headlights gave a rather limited illumination on the road, and at the same time did not produce the intense and blinding glare with which we have unfortunately become familiar since the advent of the electric incandescent lamp as a source of light for this purpose. The incandescent lamp with highly concentrated filament, when used at the focus of a parabolic reflector throws a beam of very high intensity—a beam which is capable of giving an excellent driving light, but which under many conditions produces an insufferable and intolerable glare dangerous to the other users of the highway.

INEFFICIENCIES OF EARLY LEGISLATIVE CONTROL.

As a result of protest against the dangerous glare of powerful headlights, legislation has been enacted from time to time for the purpose of controlling the use of such headlights. The exact method of control which should be adopted had to be devised as an entirely new matter, and hence legislative enactments were in the beginning very broad and indefinite. In general the laws stated, and do yet state, that headlights should not produce a dangerous glare or dazzle. Legislation of this character, however, had very little effect in eliminating the evil inasmuch as neither the legislators nor the traffic police officers nor the public knew what were the necessary means to adopt to accomplish this elimination of glare while retaining the light necessary for the safety of all users of the highway. To make the provisions more definite further legislation has been passed requiring that no portion of the direct reflected beam of the headlights, when measured at a distance of 75 feet or more in front of the vehicle, should rise more than 42 inches above the level surface on which the vehicle might be standing. In some states it was provided that state officials should pass judgment on various types of headlighting equipment and should approve or disapprove them in accordance with whether they meet the above requirements or not. The difficulty which was met in the case of this type of legislation was that it is practically impossible to say what the limits of the direct reflected beam are. With certain types of headlight glasses, namely, the scattering or diffusing type, the beam is broken up, so that the portion which comes by reflection is indistinguishable from the portion which proceeds from the lamp itself. Makers of this type of device have claimed that there is no direct reflected beam, a claim which evidently leads to an absurdity. · Furthermore, the difficulty arises that if all of the direct reflected beam from headlights

*Delivered before the Joint Meeting of American Institute of Electrical Engineers and the Illuminating Engineering Society, December 8, 1919, at the Engineers' Club of Philadelphia. Reprinted by courtesy of the *Journal of the Engineers' Club of Philadelphia.*

FIG. 1. CAR 200 FEET AWAY

FIG. 2. CAR AT 100 FEET IN PASSING POSITION

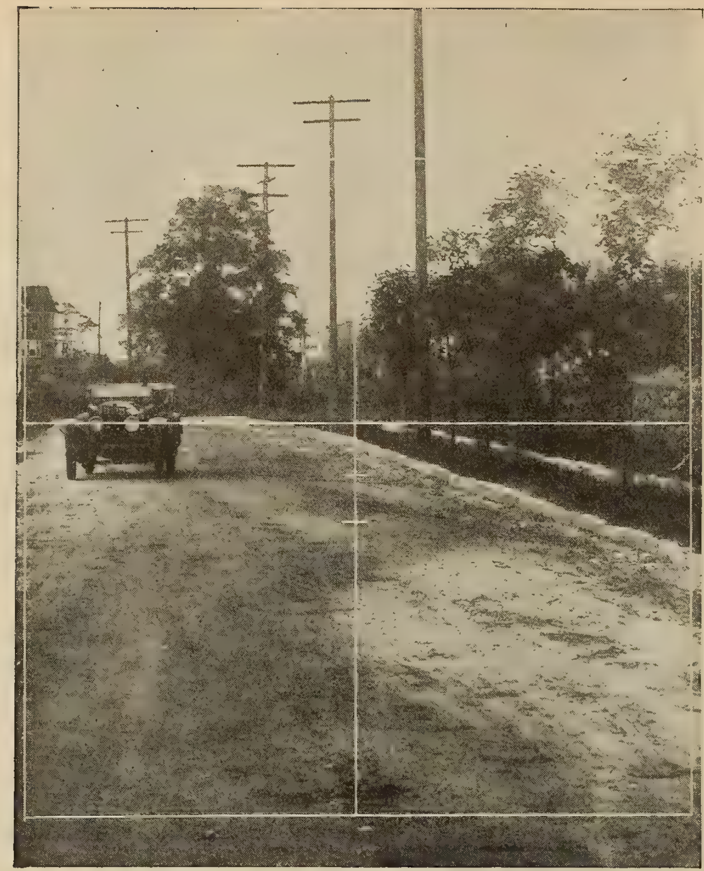


FIG. 3. CAR TURNING OUT TO PASS

were cut off at a level 42 inches above the road, it is doubtful if the remaining light above the 42-inch line would be sufficiently strong to enable the driver to proceed with safety to other users of the highway. The judgment of administrative officials under this proviso was in general arbitrary and personal, had no scientific basis, and hence no basis on which uniformity of judgment could be founded. In general this type of legislation has been found ineffective.

VARIED INTERPRETATIONS OF PRESENT LAWS.

There have been some attemps to reduce the matter to a scientific basis. In St. Louis, as a result of a decision reached that headlights of more than 1200 candlepower would produce dangerous glare, a huge photometer was built and set up in such a way that a car could be placed in front of it and the beam of the headlights measured to see whether it came above or below 1200 candlepower. If it came below, the headlights were approved. In the Province of Ontario, as a result of certain experiments, the glare limit was fixed at 800 candlepower. In Vermont, the University of Vermont conducted experiments on headlights, but it is not evident from their report that approvals of headlighting devices were based strictly upon the findings of their tests.

Matters were in this state when the Illuminating Engineering Society appointed a Committee on Automobile Headlighting Specifications. The work of this committee which has been directed toward the formulation of specifications for acceptable headlighting devices will be described in some detail. This committee decided that the first thing to do was to get some line on how much light is necessary to comply with the general provisions of a headlighting law. At the time New York State was just in the process of revising its legislation on these lines, and the New York State Law was taken as a point of departure. This law provided in brief that the headlights must render visible a person, vehicle or other substantial object 200 feet directly in front of the car, and that no dangerous glare or dazzle should be produced. The committee therefore decided as a first step to make experiments which would give some information as to the limitations of the light required to comply with the provisions of the law. In the first place, how much light is necessary to render visible an object 200 feet directly in front of a car, and second, what is the limiting value of the beam in a driver's eye beyond which the glare becomes intolerable?

Experiments were conducted on a dark road. A pair of headlights arranged with a storage battery, a rheostat and an ammeter were set up on this road, and back of them a seat representing the driver's seat. A similar pair of headlights similarly equipped were set up to the left of these 100 feet down the road, the rheostat, however, being under the control of the person occupying the driver's seat behind the first headlights. About fifty observers were employed, these being illuminating engineers, automobile engineers, private car drivers, chauffeurs, traffic officers, state officials and others, all of them competent to form intelligent judgment on the question at hand. The operation was as follows:

The observer sat in the driver's seat and adjusted the rheostat of the lamps in front of him until he had sufficient light to see men walking across the road 200 feet away. The value of the light so required was determined. Maintaining the light at that value, he switched on the other pair of headlights facing him and adjusted their brightness until he reached a point where he considered that any further light would produce a glare beyond the limits of toleration. The light reaching his eyes under those circumstances was also measured.

A study of the fifty sets of entirely independent results so obtained revealed, as was to be expected, very wide variations. For purposes of visibility the lowest man wanted 1200 candlepower and the highest 18,000. With respect to glare the lowest man would stand but 80 candlepower, while the highest accepted 800 candlepower. Of course, these were personal judgments. but the results tell us what we want to know, for the definition of a satisfactory headlight depends largely on the driver's own idea of what he wants, and so the data so obtained, while referring only to stationary lights, and while showing marked inconsistencies, were of great value.

HEADLIGHT ACCEPTABILITY TESTS.

About this time the Secretary of State of New York applied to the committee for specifications under which acceptability

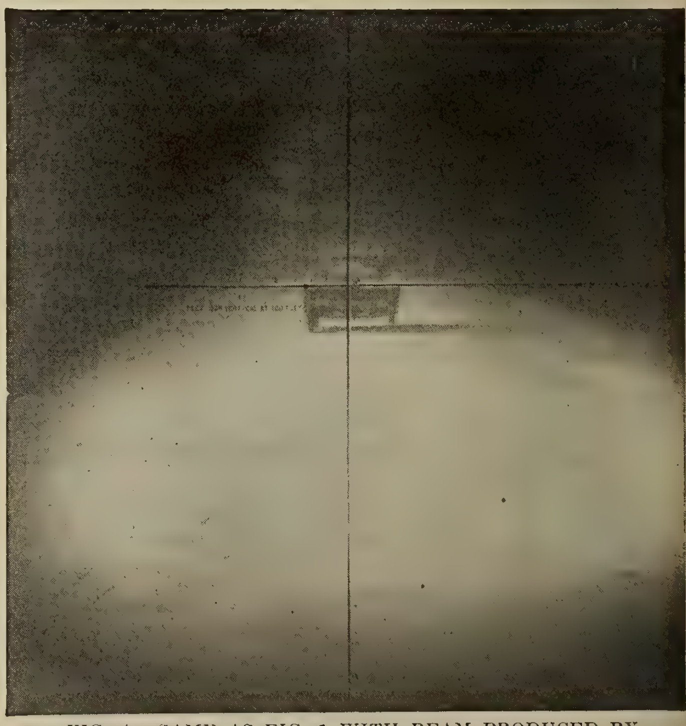


FIG. 4. SAME AS FIG. 1 WITH BEAM PRODUCED BY PRISMATIC FRONT GLASSES

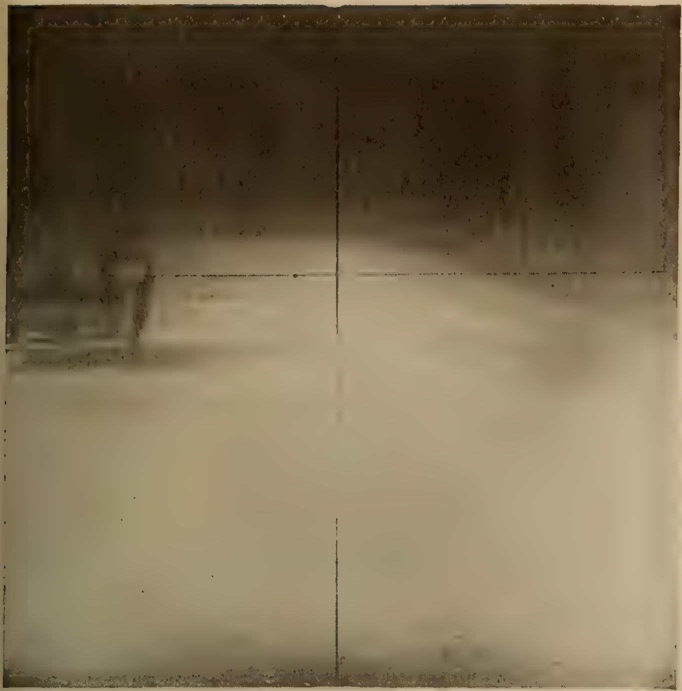


FIG. 5. SAME AS FIG. 2 WITH BEAM PRODUCED BY PRISMATIC FRONT GLASSES

tests of headlighting devices might be made for him as provided in the law. In order to arrive at the limitations which must be incorporated in such specifications, the committee did not consider that the results of the stationary test were sufficient, but proceeded to inaugurate running tests in which two cars were used similarly equipped and in which the beam was studied photometrically. As a result of numerous running tests with varied beams and with skilled observers the conclusion was reached that for the purposes of a legally restrictive specification the values which had been found as outside values in the stationary test might be adopted. That is to say, it was clear that the beam down the road should not be less than 1200 candlepower, which was the requirement of the lowest man in the stationary test. It was also evident that the glare reaching the eye of an oncoming driver at a distance of 100 feet should not be greater than 800 candlepower, which was the highest glare value accepted by any of the observers in the stationary test. Therefore, with these values fixed, a specification was drawn requiring a candlepower in the beam between the horizontal and the road level 200 feet from the car not less than 1200 candlepower, also restricting the beam at a point 100 feet in front of the car, 7 feet to the left of the axis of the car and 60 inches above road level to 800 candlepower. It was also provided that the candlepower directly in front of the car and 60 inches above the road level should not exceed 2400. The reason for the adoption of these positions for measuring the glare are as follows: If 800 candlepower is the limiting value for tolerable glare at 100 feet, as the distance becomes greater this value can be increased. For instance, the corresponding value at a distance of 200 feet would be four times as great or 3200 candlepower. It was considered, therefore, that directly in front of the car a higher value than 800 could be adopted, because an on-coming driver would never be directly in front of the car at as short a distance as 100 feet. Therefore the value of 2400 candlepower was allowed. At a distance of 100 feet the on-coming driver must have turned out to pass. His eye, therefore, may be assumed to be approximately 7 feet to the left of the axis of the car and at a distance of 60 inches above the roadway, and at this point the light is restricted to 800 candlepower. It will be noted that a height of 60 inches is chosen, which is a representative height for the driver's or pedestrian's eye above the road level rather than 42 inches, which is a figure of no particular significance.

Specifications including these limits were adopted by the Secretary of State of New York after a public hearing in which the various interests were represented and presented their views. Since that time the State of California has adopted the same values.

RECOMMENDED ALTERATONS IN PRESENT HEADLIGHT SPECIFICATIONS.

The Committee on Automobile Headlighting Specifications has never been satisfied that the value of 1200 candlepower for the driving light is sufficient, and at the time of the adoption of the 1200 candlepower figure the members went on record as favoring a higher value which, however, it was believed inadvisable at that time to put into the specifications. Since that time the committee has definitely recommended that the driving light should be four times as intense, namely, 4800 candlepower as the minimum. It has also recommended that headlighting specifications provide for a proper spread of the beam toward the right of the axis of the car; this for the purpose of revealing pedestrians on the road and of showing the curb and ditch. Its later recommendation, therefore, includes the proviso that 7 feet to the right of the car and The State of Connecticut has adopted these latest recommenda-
The State of Connecticut has adopted these laest rcommndations of the committee and has made its acceptability tests in accordance with them. The State of Pennsylvania has adhered to the New York State practice, excepting that it has improved upon it by requiring that 100 feet ahead of the car and 7 feet to the right there must be a minimum of 800 candlepower, a proviso which is in accordance with the committee's ideas, but which does not go quite so far as the committee would like to go.

It should be understood and borne in mind that these specifications on the part of the committee are not intended to describe the best headlighting practice. They are intended to be applied to the restrictions applied by administrative officials and are drawn with the idea of working a minimum hardship upon those who already have made an attempt to comply with the requirements of the situation. Hence many devices which from the point of view of the illuminating engineer or of the electrical engineer or of the mechanical engineer are decidedly inferior, are capable of complying with these specifications. However, a strict compliance with them

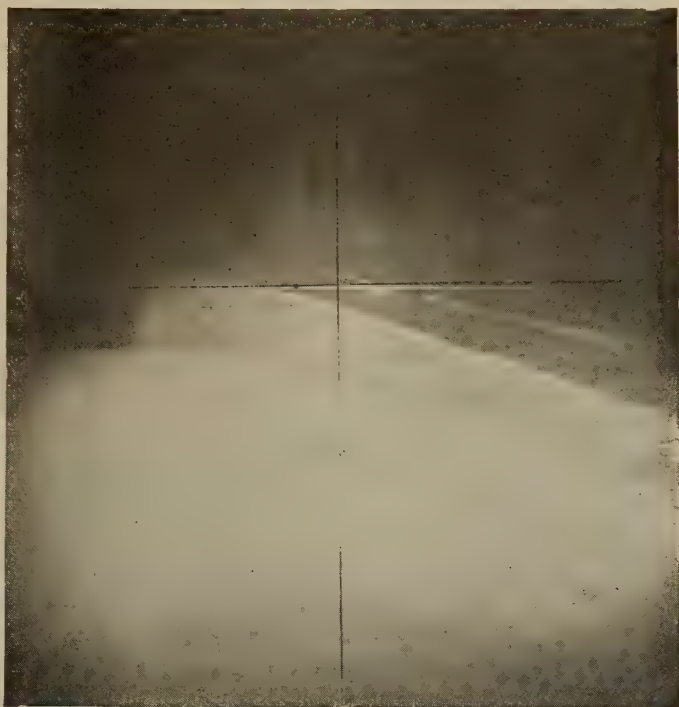


FIG. 6. SAME AS FIG. 3 WITH BEAM PRODUCED BY PRISMATIC FRONT GLASSES

will insure that devices producing a really undue glare will be ruled off the road, and conditions to this extent will be greatly improved. Those who are using devices which, while they do not produce an undue glare, also do not produce good driving light, will after a time come to find that they are at a disadvantage by the use of such devices and will exchange them for better ones; that is, the bad devices will be ruled off the road, the fair to middling devices will gradually disappear, and it is reasonable to expect in time that motor cars will light the road reasonably well both from the point of view of the driver and from the point of view of others. One effect of the specifications is to encourage the efficient devices; that is, those which throw the light on the road where it is wanted and not over the entire surrounding scenery where much of it is wasted.

MODEL HEADLIGHT LAW.

The committee further in connection with the Committee on Lighting Legislation of the Illuminating Engineering Society has prepared a proposal of a model headlight law. This proposal contains a number of very interesting and important suggestions, one of which should be of great interest to motorists. This is that testing stations should be authorized or licensed, where the headlights on any car could be tested for a nominal sum. Garages, for instance, might undertake this work after having convinced the authorities that they have the necessary equipment and technical knowledge. Then traffic officers should be authorized to stop a driver whose lights appear to be glaring and to give him a summons to appear at one of these testing stations to have his lights tested within a certain time. This should have the effect of eliminating from the road all cases of glare excepting such as result from willful disobedience of the law, and those cases could readily be dealt with by ordinary legal processes.

It should be clear from the foregoing that a start has been made on the regulation of automobile headlights along scientific lines. With four states approving headlighting devices as a result of scientific tests made under specifications which are fundamentally the same, a beginning has been made toward interstate standardization which is a matter very greatly to be desired. Every state which adheres to this method adds a good deal to the accumulated results. It is to be hoped that through the influence of the various automobile associations, future legislation may be guided along these lines. It is only by adherence to scientific methods based on fundamentally correct experimental results and representing a satisfactory engineering compromise between the demand for more light and the demand for less glare that sound and permanent results are to be expected.

For purpose of demonstrating the points made, Mr. Little threw on the screen lantern slides showing, first, the appearance of a car on the road 200 feet away; second, a car turning out to pass another car—under this condition the headlights of the car are pointing at a considerable angle from each other; third, a car 100 feet away in the passing position. On the screen image of each of these slides was thrown the beam from an automobile headlight and this beam was modified by tilting the lamp, by putting on a prismatic front glass, and by putting on a scattering front glass. The results showed that the unmodified beam when placed horizontal would throw a bright light in the on-coming driver's eyes. The unmodified beam tilted would avoid this glare, but produce an insufficient light at the sides of the road. A prismatic front glass would divert the light toward the road, giving good road illumination and keeping down the glare and at the same time illuminate the sides of the road. A scattering front glass would produce a light more or less uniformly distributed over all objects in view.

Development of the Internal Combustion Engine*

Its Past, Present and Future

By T. Blackwood Murray

During the past 25 years there has sprung into being a branch of mechanical engineering which has already become an important subdivision, namely, the manufacture of light internal combustion engines for the propulsion of motor cars, motor boats, flying machines, and such like, and as I happen to be the first president of this institution directly connected with this branch of the profession, I feel that it is a great honor to that section that a motor car manufacturer should have been called to the chair of this institution, and it is natural that I should wish to direct your attention this evening to some of the features of mechanical transport.

Some 35 years ago Gottlieb Daimler conceived the idea of constructing a light high-speed internal combustion engine for the purpose of propelling a tricycle. At that time the only gas engines in existence were heavy, cumbrous prime movers, and built purely for stationary purposes.

A few years later the manufacture of this light Daimler engine was taken up by Messrs. Panhard and Levassor, of Paris, and some of them were exhibited at the 1889 Paris International Exhibition, and attracted considerable attention there. In the affairs of mankind it has been well said that it is only in the retrospect that we can properly appreciate a man's work and put its true value upon it, and looking back over the past 25 years one realizes how much the motor car industry owes to Panhard and Levassor, particularly the latter, for the very valuable work which they did in five years prior to 1894 in evolving a practical road carriage to be propelled by the Daimler engine. By that date they had evolved a vehicle which comprised a great many of the essential features of the standard gasoline motor car of the present day. For instance, the engine was mounted in front of the vehicle under a bonnet with the starting handle in front. From the engine the power was transmitted through a spring-actuated friction clutch normally in engagement, and disengaged by a pedal for the purpose of changing gear. Changes of gears were obtained by sliding into mesh suitable pairs of spur wheels mounted on parallel shafts. Three speeds and a reverse were provided, and a foot-brake operated by a second pedal, and a second brake operated by a hand lever. There was also a pump for circulating the cooling water. All these points are standard practice today, and are accepted as matters of course, but we should realize what an enormous amount of thought and ingenuity must have been expended upon the problem of conceiving practicable methods of applying the power of the Daimler engine to the propulsion of a road vehicle, and to invent and design suitable mechanism to accomplish these ends. That these devices have stood the test of time is indeed a great compliment to Monsieur Levassor's skill and ability. To refer more particularly to one of these mechanisms, namely, the sliding speed-change gear—this in the early days was greeted on every hand with derision, and an early decrease predicted for it. Indeed there are few engineers who have not at some time or other scoffed at its crudeness. Even Monsieur Levassor, when twitted about it, remarked—"*C'est brusque et brutal, mais il marche.*" The

*Presidential address before the Institution of Engineers and Shipbuilders in Scotland, November 18, 1919.

fact remains that it is today a proved and satisfactory device, and is indeed almost in universal use. With the enormous improvement in materials available since Levassor's day, and attention to the fundamental points of design, the gear-box of a modern vehicle gives little trouble even in the hands of an inexperienced driver, and with a moderate amount of skill gear changing can be effected noiselessly and without shock.

Closely following Levassor's work several other engineers produced motor vehicles propelled by these Daimler engines, or one of similar design, and in 1894 sufficient interest had been aroused to induce the *Petit Journal* to organize a race for motor vehicles between Paris and Rouen, and the laurels were easily carried off by the Daimler engines. There is little doubt that much more attention would have been given to the matter in this country had not the development of the motor car been rendered impossible by the Locomotives on Highways Act, which at that time only permitted a motor vehicle to be used provided it was preceded by a man on foot carrying a red flag, which limited the pace to 4 miles an hour. But for this fact I have no doubt that this country would have had a more creditable record in the early development of the motor vehicle. In spite of ridiculous and restrictive legislation, however, several progressive men either built motor vehicles of their own design or obtained from the Continent such crude models as were then being manufactured, and set out to evolve more practical motor cars. In the autumn of 1895 one of these experimenters was fined for driving his vehicle in Argyle Street without having a man in front bearing the red flag. It was not until the autumn of 1896 that the law was amended, and motor cars became legal on the highways up to a speed of 12 miles per hour in England and 10 in Scotland. Since that date the industry has gone steadily ahead in this country, though in the early days there was much prejudice to face and many difficulties to be overcome.

The car which won the Paris-Rouen race weighed about 1,300 pounds, and was fitted with an engine developing about 3½ horse-power; it therefore developed 1 horse-power per 370 pounds of weight. Today an average allowance for a passenger motor vehicle is about 1 horse-power to 80 pounds of weight, and a recent writer on this subject hazarded the prediction that, as a result of the influence of the development of airplane engines, the ratio would probably be increased to 1 horse-power per 56 pounds of weight within the next few years. This, however, does not indicate the record which has already been reached in this direction. Recently a two-seated light car fitted with an air-cooled engine has been put upon the market, which claims to have a ratio of 1 horse-power per 24 pounds of weight. The early Daimler gasoline engine fitted to the first Panhard-Levassor car was a two-cylinder engine operating on the Beau de Rochas cycle, and gave one impulse or working stroke per revolution, but the mechanical balance was poor. A few years later considerable advance was made by the introduction of the four-cylinder engine giving two equally-spaced impulses per revolution, and having a fair balance of moving parts. The great majority of engines used for car propulsion today are of this type. About 1903 a considerable advance was made by Messrs. Napier by the introduction of the six-cylinder engine, giving three equally-spaced impulses per revolution, and having a perfect mechanical balance. A properly constructed six-cylinder engine runs with great smoothness, and gives a reasonable equable torque. Quite a number of cars with eight-cylinder engines are now being built, and even twelve-cylinder engined cars are not unknown.

The early motor-car engines only ran well at one speed and approximately full load. This was largely due to the fact that these engines were fitted with carburetors having no automatic regulation, and only supplying a proper mixture to the engine under these conditions. At any other speed or load the mixture was either too rich or too poor to ignite with certainty. The ignition also was by means of hot tubes, which necessitated a fairly constant compression in the cylinders to be effective, and these early engines were consequently controlled by a hit-and-miss type of governor, which either gave the engine a full charge or none at all. The laws governing the flow of air and fuel were investigated, and compensating devices were devised to ensure that the mixture of fuel and air supplied to the engine would be of the desired proportions under all conditions, and some of the later devices attain this in a wonderfully simple fashion. The shortcomings of the hot-tube ignition as fitted to the earlier engines were soon realized, and within a few years it had entirely given place to electrical ignition. Bearing in mind the difficulties that had to be surmounted in evolving an electric generator of small dimensions and light weight, capable of generating throughout a wide range of speed an electric current at a pressure of several thousand volts, we realize that the modern high-tension magneto is really a marvelous achievement. There are, of course, other systems of electrical ignition, but I have referred to the principal type.

For no very obvious reasons the earliest engines had automatic inlet-valves, but these were unreliable, and were soon replaced by cam-operated valves, which could be relied upon to open and close at the proper periods. From a crude system

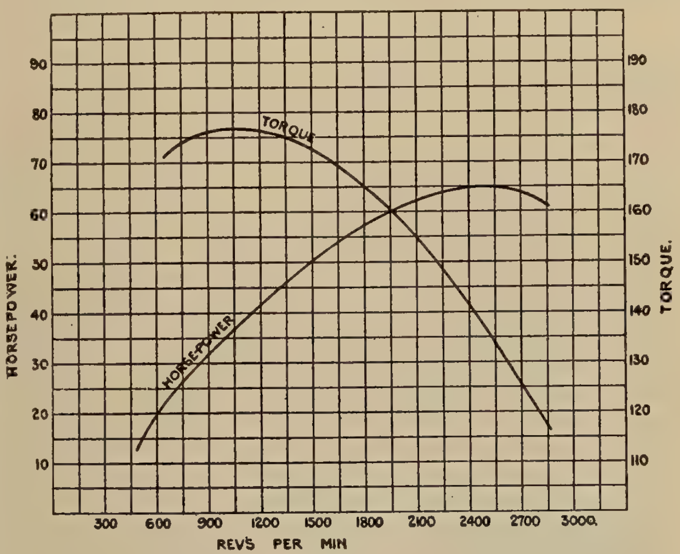


FIG. 1. TYPICAL BRAKE HORSE-POWER AND TORQUE-CURVES OF A MODERN MOTOR-CAR ENGINE

depending largely upon splash, the lubrication of engines has been studied down to the minutest detail, and in the best modern practice the lubrication is by pump, and entirely automatic, which only requires attention at infrequent intervals.

The early engines were only capable of a maximum speed of about 1,500 revolutions per minute, but the torque developed at this speed was practically nil, the torque being a maximum at about 500 revolutions per minute, rapidly dropping off beyond this speed. Today engines will run comfortably under full load at 2,000 revolutions per minute, and may in some cases be accelerated up to over 3,000 revolutions, the maximum horse-power being developed round about 2,500 revolutions per minute.

Fig. 1 gives the typical brake horse-power and torque curves of a modern motor-car engine.

While the weight of the earliest motor-car engine was approximately 50 pounds per horse-power, an average figure for a modern engine without fly-wheel may be given as 8 pounds per brake horse-power, and we may reasonably expect this figure to be reduced to about 5 or 6 pounds in the future.

The question of fuel economy is an important one in any engine intended for automotive purposes not only because it directly affects the running costs, but where considerable distances are to be traversed, the weight of fuel carried and the size and weight of the necessary tanks become considerable.

The following table shows the brake thermal-efficiencies of different types of engines, and from that table it will be seen

that the modern motor-car engine occupies a fairly satisfactory position

Comparative Brake Thermal-Efficiencies.

Locomotives		4 to 6 per cent.
Steam	Compound (non-condensing) including boiler	8 to 12 ,, ,,
	Compound (condensing)	10 to 16 ,, ,,
	Parson's turbine (including boiler)	15 to 18 ,, ,,
Internal Combustion	Petrol (automobile)	22 to 24 ,, ,,
	Petrol (aero)	26 to 28 ,, ,,
	Coal Gas (stationary)	29 to 31 ,, ,,
	Diesel	33 to 35 ,, ,,
Combined I.C. and Steam	Still Engine (efficiency already obtained)	41 ,, ,,
	Still-Diesel combination (probable efficiency)	44·5 ,, ,,

Owing to the fact that a large amount of reserve power is necessary in a motor-car engine to give rapid acceleration, or to meet the higher tractive effort required for exceptionally heavy-road conditions, or for climbing modern gradients without changing gear, the engine is for the greater part of the time running under considerably less than full load—in fact, for 90 per cent of the time it may be said to be running at from one-third to one-half full load. Obviously, therefore, it is of great importance that it should have a high fuel efficiency under these conditions. In Fig. 2 is shown the fuel-consumption curve of a normal modern motor-car engine running at 1,000 revolutions per minute, from no load up to full load. At full load the efficiency is good, but at half load the fuel consumed per brake horse-power per hour is 25 per cent greater than at full load. At one-third load the conditions are still worse; the consumption is 60 per cent greater per brake horse-power per hour than at full load. In fact, over average running conditions the fuel consumption is 50 per cent greater than the economy attainable at full load. Now, for the conditions I have been describing, the ideal engine should have a fuel-consumption curve somewhat like the dotted line A in the diagram, giving maximum economy from one-third to one-half load, and still a reasonable economy at full load and at no load. Attempts have been made to secure this by providing engines with variable clearance-volumes or by supercharging at full loads, but, so far as I am aware, no conspicuous success has as yet been obtained.

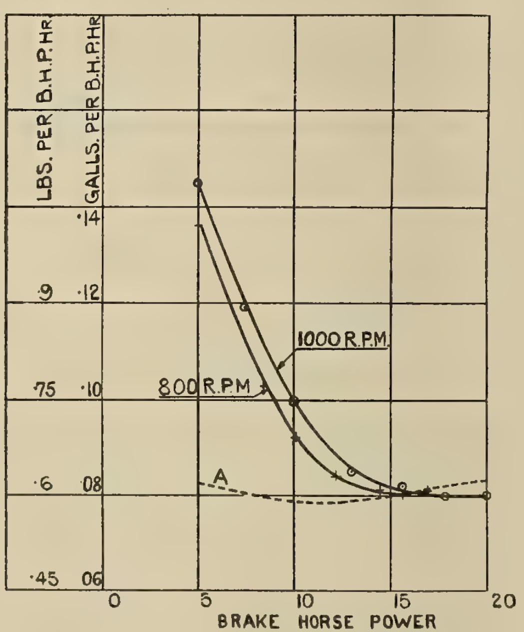


FIG. 2. FUEL CONSUMPTION CURVE OF AN ENGINE RUNNING AT 1,000 REVOLUTIONS PER MINUTE

The present engine is far from being ideal, and leaves much room for improvement, one great shortcoming being that it is not self-starting. The mere fitting of a modern so-called self-starter does not alter the fact that the engine is an inert mass until it is cranked, and this is a serious disability which must be overcome. The ideal engine for vehicle propulsion would be one which was reversible, really self-starting, and having an emergency torque about three or four times the normal, such as, for instance, is obtained in a compound engine by admitting steam to the low pressure cylinder. It goes without saying, of course, that it must be light, simple in design, require next to no attention, be moderate in cost, and reliable and economical in service. The ideal engine which doubtless will be ultimately evolved may quite probably be an entire departure from the internal combustion type as it is known today.

While the question of the speed of a vehicle on the road is not of primary importance, it is perhaps the feature which ranks foremost in the public conception. In this connection, we find a very curious analogy between public opinion as to the safe speed on railways in early days, and public opinion 70 years later in connection with the speed of motor vehicles. When in 1821 the first railway between Liverpool and Manchester was projected by the great engineer, George Stephenson, the fact that he proposed to work the line with an engine running at 12 miles per hour was held up as of itself sufficient to stamp the scheme as a bubble. "Twelve miles an hour!" exclaimed the *Quarterly Review*, "as well trust oneself to be fired off on a Congreve rocket." Experience soon proved, however, that these fears were groundless, but that did not prevent very similar fears being expressed in 1896, and as a result, when motor cars were first legalized on Scottish roads, the speed was limited to 10 miles an hour, although in a few years that was raised to the more reasonable limit of 20 miles an hour, and but for thoughtless and inconsiderate driving in a few isolated cases, this limit might ere now have been considerably increased.

Having these facts in view, it is extremely interesting to note that, in 1894, in the Paris-Rouen race, the average speed of the winning car was 12 miles per hour; whereas, in the Grand Prix of 1914, over a difficult course extending to 466 miles, an average speed of 65 miles per hour was attained; while last spring, on a motor racing track, the mile was covered in 24.02 seconds, representing a speed of 149.8 miles per hour.

In the short space of a quarter of a century the safe speed of passenger transit on ordinary roads has been practically quadrupled. In future, when we have, as we no doubt will have, special motor-vehicle highways with recognized up and down tracks probably running over and under bridges to eliminate the crossing dangers of other intersecting highways, the speed of motor vehicles on these roads will at least equal that of express trains today, and with perfect safety.

Before leaving the question of speed, it should be noted that the question of rapid acceleration is an important one for the motor-car designer. Under ordinary road traffic conditions it is, of course, impossible to maintain a constant velocity from start to finish of the journey. A modern high-grade passenger motor car is capable of acceleration on the level from a speed of 10 miles per hour to a speed of 30 miles per hour in about 10 seconds, and this capacity for rapid acceleration has a very important bearing on the total time required for any given journey. It also has an important psychological effect on the driver, as the knowledge that he can rapidly regain a high speed make him much more willing to reduce the speed to well within safe limits whenever occasion demands.

One of the most notable developments of the past 25 years has been in the materials available for construction. While in the early years of the motor-car industry a good quality of mild steel was practically all that was commercially obtainable, today we have a large choice of alloy steels which has

enabled designers in many cases to cut down the weight of a part to one-third of what it would necessarily have been with the older materials.

The accompanying table shows the enormous advance which has been made in the production of high-grade constructional steels.

Again, in modern engineering, the designer has not only a much better knowledge of the materials he is employing, but he can rely upon their being homogeneous and really having

Comparative Physical Properties of Steel.

	Ultimate	Yield.	Elongation in 2 inches.	Reduction of area.
	Tons.	Tons.	Per cent.	Per cent.
Medium carbon steel (normalised) -	30	16	25	45
Bright drawn mild-steel bars. Air Board Specification S1, Part 1	35/42	25	15	40
3 per cent. nickel steel bars (heat treat.). Air Board Specification S8 - -	45	32	24	50
Nickel chrome (heat treated). Air Board Specification S11 - -	55/65	45	18	50
5 per cent. nickel case-hardening steel. Air Board Specification 3S 17 -	60	50	13	40
100-ton alloy steel bars. Air Board Specification S18 - -	100	—	8	20
Chrome vanadium spring steel -	115	110	10	—
Special alloy steel for gears, etc. -	134	106	8	15

the physical properties set out in the specification, and, therefore, it is unnecessary to use such generous factors of safety as were usual in the earliest days.

Where the designer is dealing with the problem of motor vehicle or similar structures in which saving of weight is of supreme importance, he must carefully discriminate in the case of each part, and employ only such a factor of safety as is necessary, having in view the point as to whether the structure is only subjected to such a stress as can be accurately estimated, or whether it may be liable to severe overload stresses due to shock. To take a concrete instance, consider the case of a foot-brake lever. Here it is known that the maximum stress which can be imposed is the pressure exerted by the man's foot, and if we take a maximum figure for this it is sufficient to allow a factor of safety of two with respect to the yield point of the material. While in mild steel we dare only stress the part up to 7½ tons per square inch, with 3 per cent nickel steel we can go to 20 tons, and with nickel chrome steel we can go to 30 tons per square inch. On the other hand, there are parts such as axles where the dead-load stresses may only represent as little as 8 per cent of the maximum stresses which may be imposed by exceptionally severe road conditions, and the impossibility of contending with such conditions without the use of these special alloy steels will be readily appreciated.

Prior to the advent of motor engineering, the accepted dimensions and basis of design for machine-cut gearing were such as to have made the motor car an impossible proposition. To give a single instance an electric crane reduction-gear transmitting 30 horse-power at a pitch-line speed of 750 feet per minute, with velocity ratio between the two shafts of three to one—the gears being machine cut of steel—an average size for the teeth was one inch circumferential pitch by 2⅞ inches wide. In a modern motor car gear-box, having machine-cut wheels of case-hardened special alloy steel with the same pitch-line speed transmitting the same power, and with the same speed ratio between the shafts, the following dimensions would be found very ample:—.63 inch circumferential pitch by one inch wide, and the relative weights of the two sets of gears would be in the one case 95 pounds and in the other 11 pounds; in other words, the weight of the motor-car gear is less than 12 per cent of the weight of the electric-crane gear. Where in aircraft design the weight is of supreme importance, by the adoption of still higher-grade materials still greater reduction in weight can be achieved. I do not suggest that all this reduction in weight is due to better materials; probably the two most important factors are the steps that are taken to harden the wearing surfaces of the teeth, so as to carry the enormous loads without deformation or abrasion, and the accuracy with which the teeth are formed and finished, and, in a lesser measure, the precautions which are taken to maintain correct relative position and alinement of the shafts to eliminate deflections and vibrations.

To obtain full advantages of these various alloy steels very special and accurate heat treatment is necessary at various stages of the manufacturing processes. The heat-treating department in a modern motor-car factory is a section of primary importance in charge of a technical expert, and in close touch with the works' laboratory. It embraces a variety of furnaces of different types for normalizing, carbonizing, reheating, and tempering. The trend of design of furnaces would appear to be towards the producer-gas type. The control of the temperature is of vital importance, and in the case of some steels the temperature for a given treatment must be kept within very narrow limits.

The determination of temperature is almost entirely done by means of electrical pyrometers, preferably of the recording type, so that the life history of any batch can be referred to at a subsequent date, if necessary. Batteries of cooling baths are also provided to suit each particular process, and these are carefully maintained at the required temperature.

Fig. 3, which is taken from a paper read recently by Mr. Arthur Stubbs, shows graphically the extreme importance of the correct temperature and the proper methods of cooling if the material is to have the physical properties desired for the particular duty it is called upon to perform. Failure to observe these conditions may produce most disastrous and totally unexpected results. As an instance, similar pieces of nickel chrome steel were reheated to 600° C., the one

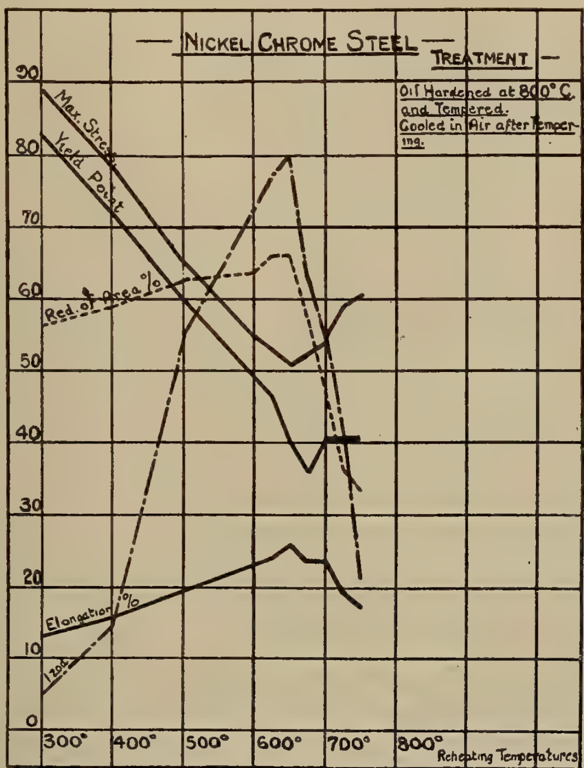


FIG. 3. CURVES SHOWING IMPORTANCE OF CORRECT TEMPERATURE AND PROPER METHODS OF COOLING

water quenched and the other allowed to cool slowly; the sample which was water quenched gave an Izod test of 52 foot-pounds, whereas the slowly-cooled test-piece gave an

Izod test of 1 foot-pound. The greater danger lies in the fact that this extreme brittleness of the slowly-cooled sample would not have been disclosed by an ordinary tensile test.

An extremely useful adjunct to the heat-treating department is the copper-plating shop. By this means the case-hardening effects can be located as desired on machined parts. By proper hardening and tempering one is able to vary the relation between the ultimate tensile strength, the elastic limit, elongation, and reduction in area, and to obtain with certainty the combination most suitable for the purpose in hand.

I cannot leave the subject of materials without referring to aluminum alloys. These are playing an increasingly important part in the construction of motor vehicles and aircraft. These alloys are largely employed in the construction of engine-cases, gear-boxes, etc., and more recently pistons have been largely made of this material. For this latter work they have the two important advantages of lightness and high heat-conductivity. To mention in particular one of these, duralumin is an alloy containing upwards of 90 per cent of aluminum, and has a specific gravity of 2.8 as compared with 7.8 for steel. In the hull construction of the R34 16 tons of duralumin were used. According to the purpose for which it is intended, duralumin can be supplied in qualities ranging from an ultimate tensile strength of 25 tons per square inch with 25 per cent elongation, to 35 tons per square inch with little elongation, the elastic limits being 13.5 and 20 to 27 tons per square inch respectively. The Brinell number for duralumin plates varies from 109 to 174, the higher value being for thin, and consequently hard plates.

Particulars of a new light-piston alloy appeared a few weeks ago in an American technical journal. Its chief constituent is magnesium, which has a specific gravity of 1.74. This new alloy is claimed to be specially suitable for pistons. Its elastic limit is from 5½ to 6½ tons per square inch, and its ultimate tensile strength from 7 to 8½ tons per square inch. It is further claimed to possess a low coefficient of expansion and high heat-conductivity; is easily machined, and less abrasive on the cylinder walls than aluminum. We may look with confidence for still further substantial advances both in alloy steels and light constructional alloys. Progress in the past is only inidcative of what will certainly be achieved in the near future.

Let us attempt to visualize the motor road-vehicle of the future, and the conditions under which it will have to work, say, 20 or 30 years hence. The recent railway strike brought home to the public the capabilities of mechanical transport, and before long the enormous importance to the prosperity of the nation of the highest possible grade of highway will be fully realized. There is probably no other national investment which will ultimately show a more handsome return.

One of the difficult and most important problems to be tackled by civil engineers is the method of constructing highways so that they will require a minimum of upkeep and provide a smooth and clean surface for traffic. The road of the future will be proportionately broad to the traffic it has to carry. It will be so constructed as to be practically dustless, and there will be an absolute prohibition against any other than rubber-tired traffic. Neither horses nor other animals will be permitted on its surface. If they are to be transported over them, it must be in trucks suitable for the purpose, as is done in railway work today. It will then seem just as reasonable to suggest driving a flock of sheep along one of these main highways as it would appear to us today were a farmer suggesting to drive a flock of sheep along a railway line. Traction engines and agricultural implements and such like will not be allowed to destroy the surface as they do at present. Sharp bends will be eliminated, and on main highways few gradients will exceed 1 in 20, and even on subsidiary roads greater gradients than 1 in 10 will probably not be permitted. The surface of these roads will also be maintained at a certain definite standard determined probably by some species of seismograph, and there will be no such thing as the road waves and pot holes with which today we are all so painfully familiar. A private owner will, in fact, have legal redress against the authorities should his vehicle be damaged through defective road surfaces. While discussing the question of roads, it will be interesting to compare, for a moment, the tractive effort necessary under various conditions. The following table gives the tractive effort required in pounds per ton to overcome road resistance:

TRACTIVE EFFORT REQUIRED TO OVERCOME RAIL OR ROAD RESISTANCE.

	Lbs. per ton
Railways—	
Main-line railways	15
Electric tramways	26-30
Road Surfaces—	
Asphalt on concrete	40-45
Smooth granite setts	50
Tar Macadam, hard	65-70
Clean wood pavement	70
Tar Macadam, muddy and sticky	95
Road metal, partly rolled	120
Tar Macadam, soft and cut up	140
Unrolled road metal	200

This shows conclusively that the question of road surface is of paramount importance and has a direct bearing on the cost of transport, and no effort should be spared to obtain the most efficient road surfaces. When it is borne in mind that a gradient of 1 in 20 necessitates an additional tractive effort of 112 pounds per ton, it becomes abundantly clear that the difference in tractive effort required to haul a rubber-tired vehicle on a first-class road as compared with an electric tramway is so moderate as to be practically negligible. On further reflection it would seem difficult to find any reasonable excuse for the retention of tramway cars, more particularly as they form a most serious obstruction to other traffic in the streets of a town or on a highway, owing to the lack of dirigibility, and the tramway lines form a fruitful source of damage to road surfaces, and constitute also a frequent cause of tire damage and side slips.

When really good roads are an accomplished fact it will no longer be necessary to have a gear-box or its equivalent in motor vehicles, and it is quite possible that it will be unnecessary in the lighter vehicles at least to provide anything in the nature of a differential gear, as the coefficient of friction between the tires and the roadway will not be such as to prevent the slight amount of slipping necessary to take place without damaging the tires.

The gradual improvement in roads will react very materially upon the design and the weight of motor vehicles. At present we are compelled to design vehicles sufficiently strong to withstand the worst conditions under which they may have to work, and in some cases the conditions are very extreme. When one can rely upon reasonably good highways much lighter construction will be possible throughout, and every pound saved in weight reacts through the whole design and throughout the life history and efficiency of the vehicle.

One great problem which demands the closest attention of the engineer is the conservation of our fuel supplies. We cannot go on as we have done in the past. The rate of consumption has been rapidly rising, as has also the cost, and supplies are far from being unlimited. Our duty, therefore, to future generations demands that the most strenuous efforts be made to conserve every ton of fuel, to increase the efficiency of thermal engines, and the various manufacturing processes in order that this end may be attained.

As long ago as 1886, Prof. J. P. Lesley, addressing a meeting of the Institute of Mining Engineers in Pittsburg, said: "I am no geologist if it be true that the manufacture of oil in the laboratory of Nature is still going on at the hundredth or the thousandth part of the rate of its exhaustion. And

the science of geology may as well be abandoned as a guide if events prove that such a production of oil in western Pennsylvania as our statistics exhibit can continue for successive generations. It cannot be. There is a limited amount. Our children will merely and with difficulty drain the dregs."

It should be clearly borne in mind that we have been in the past, and are at present, living upon capital; this, as every business man knows, is a prodigal policy, and sooner or later will lead to bankruptcy. In other words, we must live on revenue—that is to say, we must year by year obtain in some manner or other our annual supply of fuel either from agriculture or some other natural source of production. Here it is appropriate that I should make a brief reference to the possibilities of alcohol as a fuel and the report recently issued by the Government Alcohol Committee. With the desire of fostering home porduction and fuel for motor vehicles, France has for years past devoted a large amount of attention to the question of running internal combustion engines on alcohol, with considerable success. In the French War Office trials, carried out in 1910, the following very interesting results were obtained:

Petrol (gasoline).....53.2 gross ton-miles per gallon.
Alcohol fuel ....46.3 gross ton-miles per gallon.
Benzol ....57.1 gross ton-miles per gallon.

The alcohol fuel was a mixture consisting approximately of 50 per cent alcohol, 35 per cent benzol, and 15 per cent petrol.

Taking alcohol at 1s. 3d., benzol at 1s. 10d., and gasoline at 1s. 11½d. per gallon, the cost per ton-mile works out at .45d. for gasoline, .412d. for alcohol fuel, and .385 d. for benzol.

It has been clearly demonstrated that alcohol alone, or a mixture of alcohol and gasoline or similar fuels are quite suitable for the propulsion of motor vehicles, and there seems to be little doubt that alcohol will be one of the most important fuels in the future. Its merits are summarized in the following sentence taken from the British Government Committee's report:

"The outstanding and fundamental attraction of alcohol motor fuel as a substitute for any fuel necessarily derived from coal or oil deposits lies in the fact that, on account of its chief sources being found in the vegetable world, supplies of raw material for its manufacture are being continuously renewed, and are susceptible of great expansion without encroachment upon food supplies."

While the prospect of commercial production in Great Britain is not encouraging, there is every possibility that the necessary supplies of alcohol fuel could be produced within the British Empire, the raw material being obtained from tropical countries. The vegetable materials from which alcohol may be produced are so varied and widespread that there would appear to be almost no limit to supplies. There are sugar-containing products, such as molasses, large quantities of which are at present running to waste; starch-containing products, such as cereals, potatoes, etc.; and cellulose-containing products such as wood pulp.

Dr. Ormandy, in a paper read in 1913, instanced a plant intended for British Nyassaland capable of producing 600 gallons of alcohol per week from maize. The cost of the raw material only amounted to 3d. per gallon of alcohol. The other charges he estimated at 6d. per gallon, making a total cost of 9d. per gallon at the distillery. This, however, as he pointed out, is a very small plant, and from the figures given by other authorities there seems to be little doubt that alcohol can be produced at from 5d. to 6d. per gallon at the distillery. In the recent Government Alcohol Committee's Report there is indicated a very promising source—namely, flowers of the mahua tree. These the committee stated could be cultivated and delivered at the local distillery at 30s. per ton, which would represent a raw material cost of 4d per gallon. Given, therefore, reasonable excise regulations, which will no doubt come in time, there seems to be no reason why denatured alcohol fuel should not be delivered to the consumer at about 1s. 3d. per gallon.

The following table shows the comparative properties of denatured alcohol, petrol (gasoline), and paraffin (kerosene), and the cost per brake horse-power per hour with these fuels:

Cost Per B.H.P. Per Hour on Various Fuels.

Fuel.	B.Th.U's. per lb.	Brake Thermal Efficiency.	Lbs. per B.H.P. per hour.	Specific Gravity.	Gallons per B.H.P. per hour.	Price per gallon.	Cost per B.H.P. per hour.
		Per cent.					
Denatured Alcohol	11,000	30	·77	·825	·093	1/3	1·40d.
Petrol -	19,000	23	·58	·780	·075	1/11½	1·76d.
Paraffin -	20,000	20	·64	·810	·079	1/6	1·42d.

Steps must also be taken to fully utilize our natural sources of energy, such as waterfalls. We may even be compelled to devise satisfactory ways and means of obtaining mechanical energy from such sources as solar heat, wind, and tides.

Perhaps the most interesting field of application of the internal combustion engine, and certainly the most romantic, is in the realm of flight. From the earliest ages it has been man's ambition to conquer the air, and one can scarcely realize that little more than a decade has elapsed since the brothers Wilbur ond Orville Wright first accomplished a flight in a machine heavier than air driven by a gasoline engine. In this field, particularly during the war, development of design has been astonishingly rapid, and one might say with truth that the results achieved have been almost miraculous. While the Wright brothers began with an engine developing 15 horsepower, airplanes are being constructed today with one or more engines each developing 400 or 500 horse-power. One of the most successful engines of modern design develops 450 horse-power, and only weighs 662 pounds, or rather less than 1½ pounds per horse-power. Even when an engineer accustomed to motor-vehicle practice. which is thought to combine maximum lightness consistent with safety, is first brought into contact with these latter-day aero engines, he stands aghast to see how fine the limits of weight have been cut. It was stated in a recent publication that the weight-carrying capacity of a modern airplane is about 33 per cent of the total weight. It is not unreasonable to assume that in the next few years this percentage should be raised to at least 50, and upon this assumption it ought then to be possible to construct an airplane capable of carrying one man and sufficient fuel for a short journey, having a total weight of 150 pounds. The engine would probably be about 20 horse-power, of the air-cooled type, weighing not more than 20 pounds. A few years hence, therefore, we may see practical machines offered on the market enabling a man to fly from point to point with as great ease as he would cover the distance on a motorcycle today. Great progress will doubtless be made in the construction of larger airplanes and in their commercial use, though it must be borne in mind that the manipulation of these machines will always require a much higher degree of physical efficiency than is necessary for the control of vehicles running on land or water, as the landing of an airplane must always call for a cool head and sound judgment. Simultaneously with the development of the heavier-than-air machine, great progress has been made in the construction of lighter-than-air craft, and I need only refer to the magnificent feat of the Clyde-built airship R34 in crossing and recrossing the Atlantic a few months ago. It may safely be said that the rate of evolution of aircraft will largely depend upon the progress that is made in evolving new and improved prime movers. The field offered to the young engineer is illimitable.

One of the most impressive illustrations of the modern development of the light internal-combustion engine is the extent to which it was used, and the part it played, in the great war. In the air the gasoline engine alone served for the propulsion of airships, airplanes, and flying boats. On the land it was principally used for the propulsion of either passenger- or goods-carrying vehicles or engines of war, such as tanks; and also for a large number of other purposes where a light portable prime-mover was necessary. On the sea it was utilized for the propulsion of motor boats and various small craft, as well as for auxiliary purposes. At the conclusion of hostilities the British War Department had 62,000 motor lorries, 28,000 cars, and 33,000 motor cycles.

By the courtesy of the Ministry of Munitions I am able to give a statement of the total horse-power represented by the output of internal combustion engines by British manufacturers during the war.

The table is divided into three sections—namely, aero engines, mechanical transport engines, and tank engines; of the former the total production during the war amounted to the enormous figure of 7,094,000 horse-power. Dealing with mechanical transport engines, the table does not give the figures for the years 1914 and 1915, but these aggregate about three-quarters of a million horse-power, and, therefore, the total brake horse-power of mechanical transport engines produced for war purposes was 2,232,000. For tank engines the total was 340,000 horse-power, making a grand total for all classes of 9,666,000 horse-power. A prime mover that has so

Engines Produced 1914-1918 in Terms of Horse-Power.

Type.	Aug.-Dec. 1914.	1915.	1916.	1917.	1918.	Total.
Aero engines	12,000	195,000	771,000	1,973,000	4,143,000	7,094,000
Mechanical transport engines			137,000*	683,000	662,000	1,482,000
Tank engines	—	—	16,000	133,000	191,000	340,000
	12,000	195,000	924,000	2,789,000	4,996,000	8,916,000

* Four months, September to December, only.

wide and general an application merits the closets attention, and no effort should be spared to improve it.

While there has been great progress in the last 25 years in the constructional materials available for the engineer, there has also been a great development in machine-tool practice generally, and especially in the evolution of tools for the production of parts in quantity in a cheap and efficient manner, and of such high-grade accuracy as to be interchangeable. Time only permits a very brief reference to this interesting subject, but perhaps the advance made in automatic grinding-machinery is one of the most interesting developments. Not only has the grinding machine made it possible to produce with ease complicated parts such as multiple-throw crank shafts with an accuracy unapproachable even by a skilled turner, but also at far lower cost. In the process of case-hardening, a certain amount of permanent distortion inevitably takes place, and in no other way could this be rectified than by the use of automatic grinding-machines. Brought to a high state of perfection, they can deal with practically any form of surface, flat, circular, internal or external, or of irregular shape, such as cams for operating inlet and exhaust valves. Such cams can be produced commercially to a limit of accuracy of 1/1000 inch. In fact, where drop forgings are used it is no uncommon practice to dispense with the lathe entirely, and to machine and finish such parts as crank shafts and camshafts right from the forging on grinding-machines. Considerable success has also been achieved in automatic grinding-machines to rectify the teeth of hardened gear-wheels, where the slight distortion that is almost inevitable under heat treatment would otherwise set up undesirable noise.

In motor car work the diameter of the shafts is so small in proportion to the torque transmitted that the old-fashioned methods of keying are insufficient. The best modern practice is to machine 6, 8 or more key-ways equally spaced on the shaft, and these, after hardening, can be ground to accurate dimensions in suitable automatic grinding-machines.

Broaching or drifting machines are being increasingly used for producing all shapes, or holes, such as the castellated holes in the bosses of wheel parts to be mounted on a castellated shaft such as I have been describing.

I cannot omit a reference to the great advance which has been made by the introduction of what is known as high-speed steel for cutting tools. As the accompanying table shows,

	Medium steel forgings.	Hard steel forgings.	Hard cast iron.
Carbon tool steel, 1894	Feet per min. 16	Feet per min. 6	Feet per min. 15′ 6″
High-speed steel, 1906	99	41.5	52′ 0″
Increase	6 times.	7 times.	3 times.

it permitted cutting speeds to be very substantially increased, and it enabled much heavier cuts to be taken—two facts which very soon led to the complete redesign of machine tools. Much stiffer tools were required, tools running at a higher speed and of much more rigid design, so that full advantage could be taken of the new steels.

Wherever a highly-specialized piece of machinery is to be produced in quantity, the aim of the engineer must be to confine skilled labor to the tool room, and in the factory proper the tools must be as nearly automatic as possible, and should also be, as far as practicable, single-purpose tools so as to avoid all unnecessary complication in their construction. They should, in fact, eliminate the necessity for jigs.

It must ever be the engineer's aim to cut down the time required for the production of any given part to a minimum; therefore, as far as possible, similar operations on a part should proceed simultaneously. For instance, multiple head milling-machines are now built which will surface three or four faces on, say, a cylinder block simultaneously at one setting. Again, in a succeeding operation it may be necessary to drill upwards of 50 holes in the said cylinder block distributed on three or four surfaces. Machines are now constructed which will bore all these holes simultaneously at one setting. This indicates the direction in which evolution is tending, and wherever the quantities to be produced warrant the expense, it is the correct policy to adopt. It is in this connection that standardization of parts is not only of immense value to the engineer, but equally so to the benefit of the community at large. A policy of standardization must, however, be pursued with caution, for there is a tendency when standards are fixed to adhere slavishly to them with the inevitable result that progress is thwarted, and new and improved methods are thereby rendered more difficult of introduction.

While not belittling for a moment what has been achieved, the product of the automatic tool still, as a rule, leaves something to be desired. To be entirely satisfactory it must finish off the article with all necessary fillets, male and female, and all rags of every kind must be automatically removed so that the part passes on to the finished parts' store, and ultimately to the erector, then into its place without any file, reamer, or scraper touching any portion of it. It is only the country whose engineering factories adopt the higher standards that will be able to compete successfully in the markets of the world.

FIG. 1. JEFFREY PIT CAR LOADER IN OPERATION IN A COAL MINE

Loading Machines for Underground Use*

Their Efficiency in Reducing Mucking Charges

By A. M. Gow

THE desirability has long been recognized of some machine that will reduce the arduous labor or "mucking," or shoveling ore or coal into tram cars underground. Many attempts have been made to produce such machines. Machinery has been introduced into almost all other operations of mining to increase the tons per man and reduce operating cost. Even the books are kept and the bills made out by machine; but the No. 2 shovel still holds its own. It will have to give way, however, for the insistent demand for an underground loader, and the efforts that are being made to produce it cannot fail to bring about a certain degree of success.

It is not to be expected that one design of machine will meet all requirements, because the underground conditions as to head-room, tonnage, and character of material vary between extremely wide limits. A machine admirably adapted for work in one mine might prove utterly useless in another. The conditions in one mine might warrant an investment wholly prohibitive elsewhere. A machine designed to handle a large tonnage in a low coal seam would in all probability prove inoperative in an iron ore mine on the Mesabi Range. Compressed air may be the most suitable source of power in one district and electricity in another. Consequently, there is room for machines of several types differing from each other not only in detail of design but in their fundamental principles of operation. These fundamental principles have already been pretty well disclosed and incorporated in many machines, many of which have been of a more or less experimental nature.

NO ONE MACHINE MEETS ALL CONDITIONS.

The ambitious inventor would do well to examine the files of the Patent Office and familiarize himself with the state of the art and also learn as much as he can from the successes and failures of other inventors. It is usually a good plan to begin where the other fellow left off. Possibly some genius may appear with some new and revolutionary idea, but that seems hardly probable. Success is to be looked for in the proper mechanical design and proportion of parts and adaption to a given set of conditions. No one machine will meet them all.

It is useless to attempt to draw a general specification for an underground loader or to make an accurate statement as to the requirements it shall fill, except in the most general terms. Of course, it should be low in first cost, but at the present time it is almost impossible to hazard a guess as to what is the maximum price an operator can afford to pay. "Low first cost" in one place might be ruinously high in another. Simplicity of mechanism and fewness of parts are of course desirable, particularly in ore mines where the stuff handled is fine and as abrasive as emery. Inasmuch as the operators have little mechanical skill and training, the machine should be as nearly "fool proof" as possible. When the machine fails the whole mining program is liable to derangement; there is no place to put the machine and facilities for repairing it are poor. But such considerations should not be given undue emphasis. Machines on the surface break down and wear out, but operators do not go without them on that account. Furthermore, operators must not expect too much at this time. After the designer has done all he can, the machine must be really developed underground. And here the manufacturer and the user should coöperate to their mutual advantage.

There is no doubt about the demand for such machines, and the increasing wage scale and the scarcity of men able and willing to "muck" make the demand more acute. Some operators hold that, even if machines should not reduce the cost of production, there would be other gains not shown upon the cost sheet that would make the use of machines well worth while. If, in addition to doing the work, machines will reduce the cost of production, taking into consideration investment, maintenance, and depreciation, so much the better.

TIME CONSUMED IN MUCKING.

Time studies made underground in mines when a number of operations constitute a cycle and result in the production of a certain tonnage usually show that the most promising field

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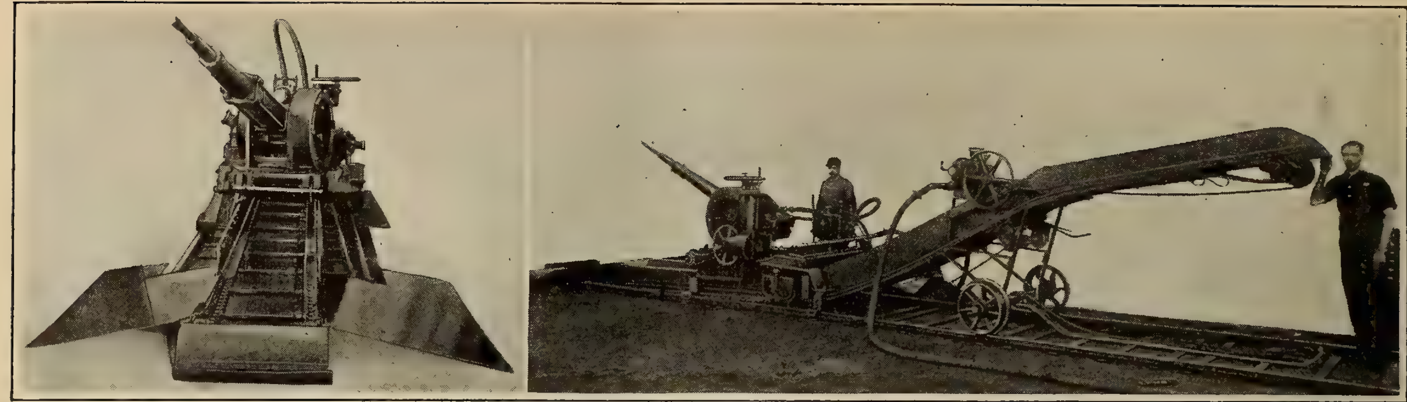


FIGS. 2 AND 3. INGERSOLL-RAND ENTRY CUTTER AND LOADER

for saving labor is upon that item where labor is most largely expended, namely "mucking." Though, of course, the time consumed in the different operations varies greatly in different mines, take it by and large in metal mines, it appears that "mucking" consumes 35 to 40 per cent of the time, the remainder being distributed over such items as blasting, blowing out smoke, tramming, trimming, timbering, drilling, track laying, and so forth, in varying percentages. Evidently the place to increase efficiency and tons per man is upon the shoveling of the dirt after it has been broken down.

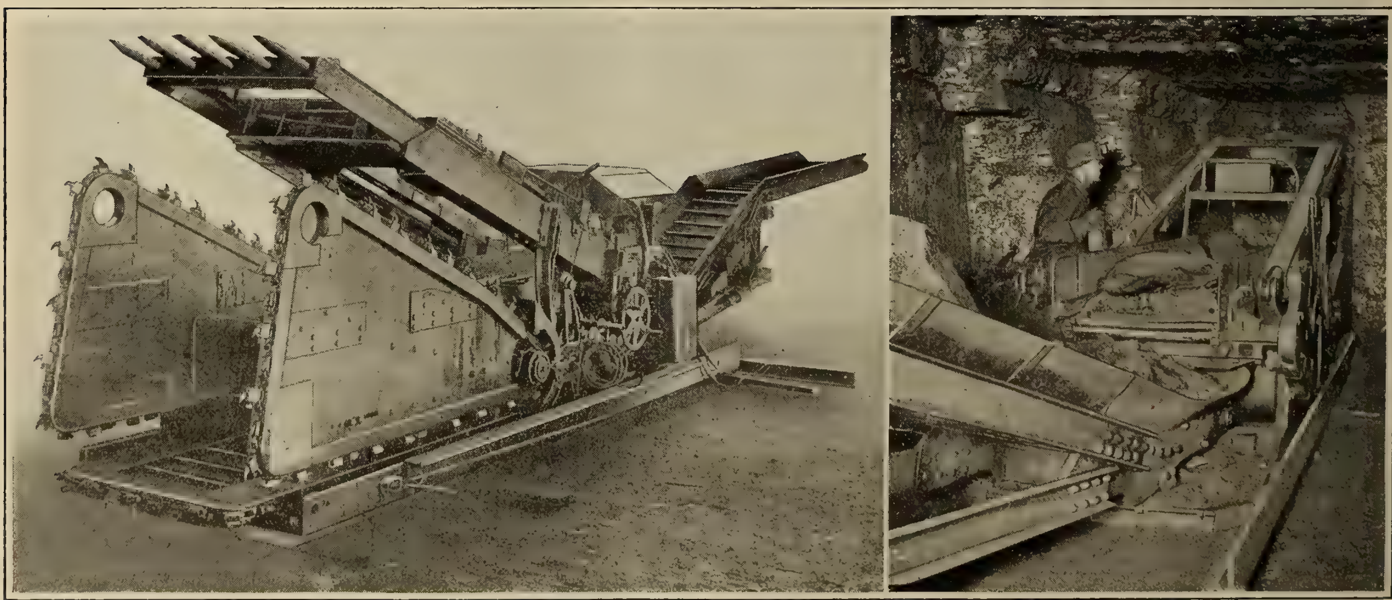
It would appear that great activity has been shown in the coal-mining industry to produce such machines than has been shown in that of metal mining. The tonnage and the character of the material are probably more favorable in coal than in metal mines. But each has its own difficulties. In no place does the problem seem an easy one.

Shoveling into tram cars really comprises two operations: digging the loose material and elevating it into the cars. Inventors and mechanics working along different lines have produced distinct types of machines, varying between wide limits in cost and weight and ranging in all degrees from extreme simplicity to great complexity. An attempt is here made to group these various machines according to their fundamental principles. Such grouping or classification is necessarily inexact, because the types overlap each other and some machines might reasonably appear in two groups. The purpose, however, is to show what has been tried from the mechanical standpoint. The economical results and effects upon the cost sheet will not be treated here. Such statements are liable to be very misleading, and results obtained with the same machine may differ greatly at different times.

It has occurred to many persons that the problem could be at least partially solved by a machine that would simply be a loader and not a digger, the idea being that the heavy labor comes in in raising the loaded shovel to the top of the tram car. Probably the simplest form in which the idea appears is in the Jeffrey Pit Car Loader shown in Fig. 1. This machine consists of a motor-driven belt conveyor set upon an incline, passing over head and tail pulleys as small in diameter as practicable. The ore or coal is shoveled by hand upon the conveyor at its lower end, and elevated into the tram car. This machine is not upon its own wheels, but is moved through the drifts on a timber truck and set in any position desired. Several years ago the Cleveland-Cliffs Iron Co. built such an elevator and mounted it upon wheels.

Inasmuch as a surface wagon loader along similar lines is in very general use, it would seem that there might be a field for this type of machine if properly designed to meet underground conditions. But apparently the feeling among mining men is that if the material has to be shoveled anyhow it might just as well be shoveled into the car and be done with it, and to fill the bill an underground loader must dig as well as load.

It has been suggested time and again that a modification of the idea almost universally used on concrete mixers could be used for underground loading. Sand, cement, and aggregate are deposited upon a pan, and then, by power means, the pan is elevated to discharge into the drum. If a similar pan were adopted to discharge into a tram car, the shoveling upon the pan would be mostly on the level, large chunks would not have to be lifted by hand, and a fair proportion of the dirt could be picked off the pile right on the pan. By



FIGS. 4 AND 5. JEFFREY-MORGAN MINING AND LOADING MACHINE

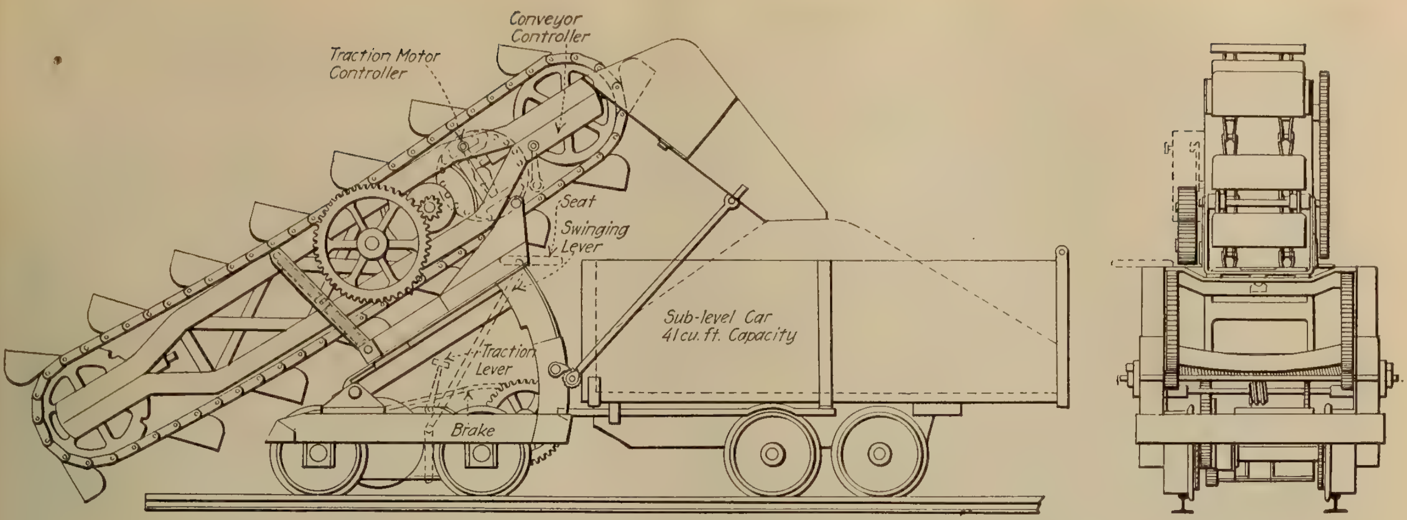


FIG. 6. McQUEEN LOADER, BUILT BY THE OLIVER IRON MINING CO.

means of a wire rope and a small winding drum, the pan could be elevated through simple guides of structural steel so bent at the top as to dump the pan into the car. In the absence of power, the drum could be turned by hand like a winch. So far as I know, this idea, although sketched in several forms, has not been reduced to practice. This proposal meets with the same objection. The machine does not dig. It only elevates. It does but half the work. If the capacity of the machine to load is limited by the shoveling capacity of the men, it is not worth while. Whether or not this position is well taken, the fact remains that although proposed and tried out some years ago, machines that simply elevate and do not dig have not come into extensive use in mining operations.

To avoid shoveling upon the conveyor the Ingersoll-Rand Co. about ten years ago developed a combination of coal puncher and elevator shown in Figs. 2 and 3. A powerful puncher is situated on a carriage over the low end of a flat conveyor. The puncher is capable of vertical and lateral movement. The first operation is to undercut the seam, then move the low end of the conveyor as far forward as possible and break the coal down upon the conveyor. Obviously, such a machine could be used only in material like coal, soft enough to be mined without blasting. In fact, one strong claim for the machine was that it dispensed with explosives. Though it has been used successfully in certain coal mines, it has not come into general use. In iron mines it, of course, is out of the question.

The same fundamental idea of breaking the coal down so as to fall upon an elevator was worked out in a very elaborate manner by the Jeffrey Manufacturing Co. It was brought out in 1913 and is called the Jeffrey-Morgan Mining and Loading Machine. It is designed for thick coal seams. It is shown in Figs. 4 and 5. The undercutting and vertical shearing are done by cutting chains, and a series of heavy reciprocating picks break down the coal upon the conveyor underneath, which discharges upon a second conveyor, which in turn, delivers into the car. This machine, though tried out thoroughly, has not proved popular. The number of movable parts, its complexity, and high cost seem to be against its general adoption, even in mines working seams of sufficient depth to permit of its operation. It can operate only in material so soft that blasting is not required.

As was to be expected, the idea of a bucket elevator has appealed to a number of ambitious inventors. On the surface, bucket elevators dig from a boot, elevate, and discharge. Why not do the same underground? Such a machine must be able to hold itself against the pile of dirt in order to make the bucket fill. Under its own power it must have forward and backward motion, and, in addition, a certain amount of radial motion to cover the width of the breast. Twenty-odd years ago such a machine was built at the shops of the Minnesota Iron Co., intended for use at the Fayal mine. It was a heavy, clumsy affair, and did not prove at all satisfactory. No photographs or drawing are available.

A machine along similar lines, though much more carefully designed, was built about five years ago in the Hibbing shops of the Oliver Iron Mining Co. It was designed by H. R. McQueen. Fig. 6 reduced from the general drawing, shows the arrangement. It gave good results so far as it was tried, but was not in service long enough to really determine its limitations. Unfortunately it was destroyed in a fire without having had a fair chance to show what it could do.

A very ambitious attempt along the bucket-elevator line is shown in Figs. 7 and 8. This machine, known as the Jackson shovel, has been built in five sizes. Obviously, the machine here shown was not designed to meet the underground con-

FIGS. 7 AND 8. FRONT AND REAR VIEWS OF THE JACKSON SHOVEL WHICH EMBODIES THE BUCKET-ELEVATOR IDEA

ditions of the average mine. A much smaller model, only 5 ft. 6 in. high, was designed for mining use. I am not informed as to what is the status of this machine today, or whether it was ever given a thorough tryout underground.

The latest aspirant for public favor of the bucket-elevator type is known as the McDermott Continuous Twin Scoop Leader and is put on the market by the Wellman-Seaver-Morgan Co. Fig. 9 gives a clear conception of it. From the

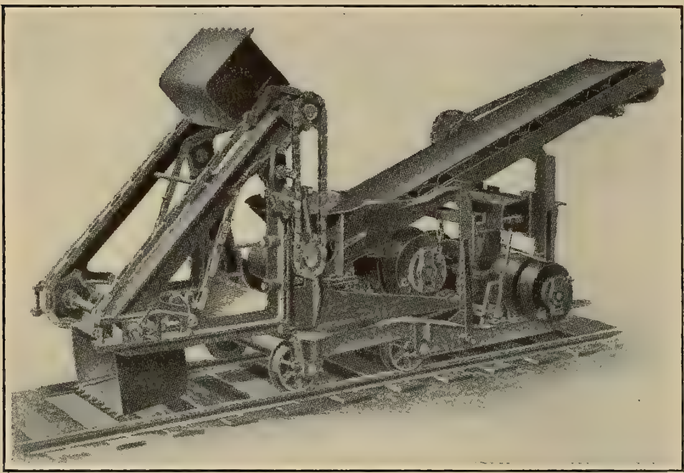


FIG. 9. McDERMOTT CONTINUOUS TWIN SCOOP LOADER

advertising literature the following description is taken: "The material is taken up by scoops or buckets on an endless chain, elevated and dropped into a hopper, which feeds to a conveyor belt, which, in turn, loads into a car. The scooping mechanism is so pivoted that it can dig as well to the side as to the front of the machine. The ore, however, being delivered to the conveyor through the hopper, reaches the car behind the loader no matter at what angle the scoop is loading. The dimensions are: Length, 15 ft. 9 in.; height, 6 ft. 7½ in.; width, 4 ft. 0 in.; weight, 8,000 lb." The averaging loading capacity is given as 45 tons per hour. It is reported as giving excellent results in at least one iron mine in Michigan.

From the mechanical standpoint, machines of this type are subject to the criticism that, inasmuch as iron ore is very gritty, the many movable parts, links, pins, and other members, incident to the use of a chain belt will be subject to excessive wear. How serious this objection is remains to be seen. It undoubtedly has less weight applied to machines for use in coal mines than in iron mines. Machines will wear out, and repairs and maintenance are an offset to the advantage and economies effected by any kind of machine loader.

Another type of machine comprises a reciprocating digging element at the front that discharges the material upon a conveyor that delivers it into a tram car in the rear. Two machines, the Myers-Whaley, built by the Myers-Whaley Co., and the Halby, built by the Lake Shore Engine Works, Marquette, Mich., incorporate the idea. These are beyond the experimental stage, having gone through several years of experience and trial and the strengthening of weak places. They show careful design, and under certain conditions of operation have proved entirely successful. The Halby has been pretty thoroughly tried out in the iron mines of Michigan, and, though it proved entirely operative so far as digging and loading was concerned, it has not met with favor sufficient to warrant its general introduction as a substitute for hand mucking. The size, weight, first cost, and mechanism of these machines, in the opinion of the operators of iron mines, leave them out of the running in competition with hand labor. The Myers-Whaley machine is shown in Fig. 10 and the Halby machine in Fig. 11. Both machines are built in different sizes. The dimensions of the No. 4 Myers-Whaley are given as length, 26 ft. 0 in.; height, 4 ft. 6 in.; weight, 18,000 lb. The No. 2 model has a length of 21 ft. 0 in.; height, 3 ft. 10 in.; weight, 9,000 lb. The latest model of the Halby, T-700, is 23 ft. 4 in. over all, 4 ft. 6 in. high, and 4 ft. 8½ in. wide.

In the Pennsylvania coal regions the Halby has been installed in several mines and is reported as giving most excellent results. A capacity of one ton a minute is easily obtained. In fact the tonnage is limited far more by the difficulty of getting cars than by the capacity of the machine to dig and load. In this respect the loading machine is ahead of the management, and if it is the intention to use machines the mine should be laid out accordingly.

Another machine which properly belongs in this group, but differs radically in mechanical construction, was built by Messrs. Billings & Middlemiss and tried out at the Morton mine, in the Mesabi Range. It is shown in Fig. 12. The digging element in this case is a large, powerful hoe, having a forward and backward motion, adapted to hoe the ore upon an apron. From the apron the ore is discharged upon a belt conveyor and thence into the tram car. The belt conveyor was operated by an air engine, and the movement of the hoe, the swinging motion to enable the hoe to cover the width of the breast and the tilting motion of the conveyor, was obtained from direct-acting air cylinders. Underground at the Morton mine the machine was reported to be digging and loading successfully, but apparently it never got beyond the development stage, and so far as I can learn it is not being exploited today.

Where stopes are high enough and tonnage is large enough, there is no reason why revolving motor-driven machines of the steam-shovel type should not be operated underground. It would seem that a small revolving shovel would go a long way to solve the problem in many mines, and, as would be expected, the idea has been mechanized along several lines. The fundamental conception is that of a shovel or dipper filled by forcing it into the pile, then raised, revolved 180 degrees, the dipper door tripped, and the load dropped into the car.

The Thew Automatic Shovel Co., of Lorain, Ohio, build a

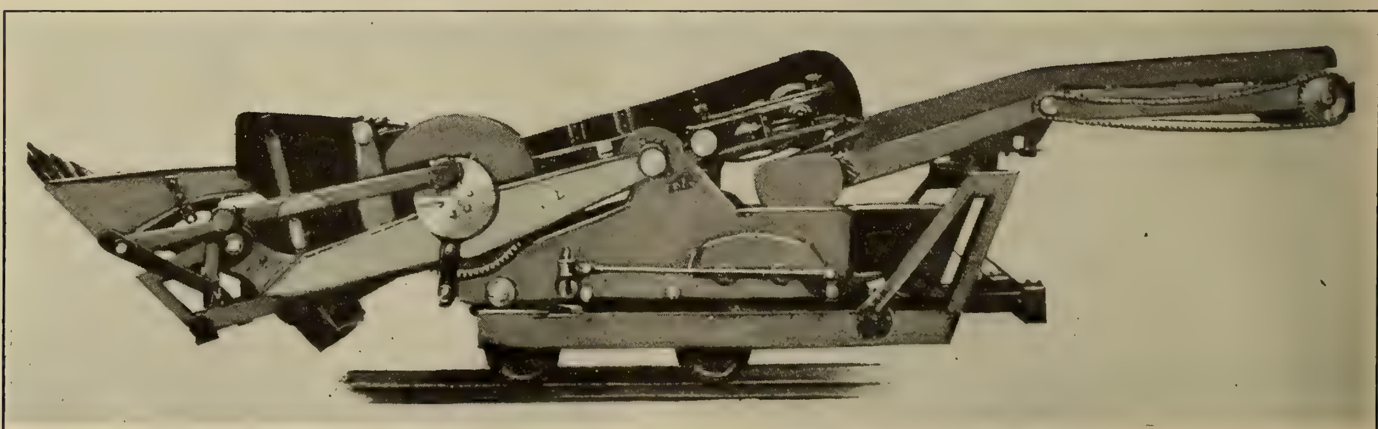


FIG. 11. HALBY SHOVELING MACHINE

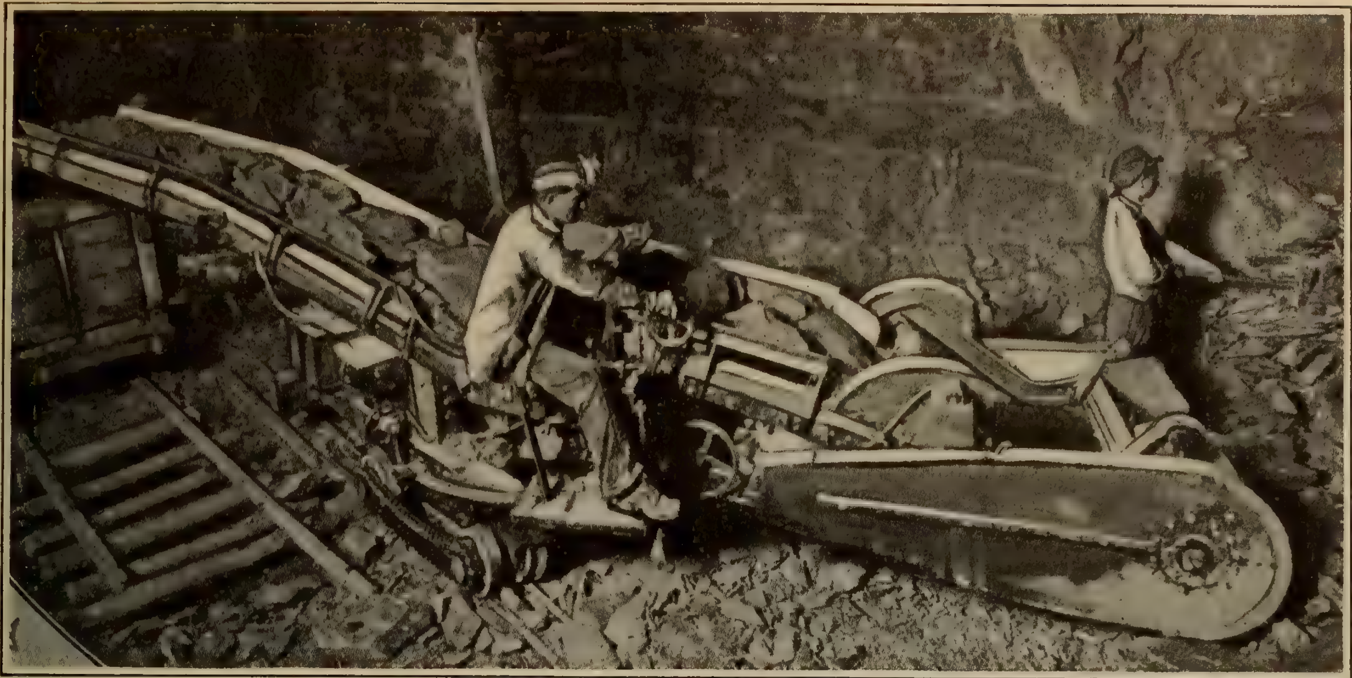


FIG. 11. THE MYERS-WHALEY SHOVEL IN OPERATION

small, motor-driven shovel especially designed for underground work. Though it is a small machine as steam shovels go, it is quite large as an underground loader. It is shown in Fig. 13. The dimensions given are over-all height, 9 ft. 0 in. to 12 ft. 0 in., over-all length about 25 ft. 0 in. One twenty-horse-power motor by means of friction clutches furnishes power for the operations of hoisting, crowding, swinging, and propelling. Where head-room will permit and tonnage warrant, there can be little question as to the operativeness of this machine.

A large builder of mining machinery is now engaged upon the development of a machine of this general type designed to work in low coal seams. A centrally located hydraulic jack, like a large drill column, holds the machine in place between floor and roof. A horizontally operating dipper stick, carrying a very flat dipper, is adapted to revolve around the central column. The dipper having been filled by forcing it horizontally under the pile, is raised, swung around over the car, and discharged by means of a pusher. Where the roof is low and the room is large the machine would seem to present many possibilities. It is not yet beyond the developmental stage, and the builders request that no photographs be published at present.

For several years Captain Samuel Hoar, a mining man of Virginia, Minn., has worked to produce a revolving shovel small enough and strong enough, sufficiently simple and "fool proof," to meet the demand upon the iron ranges of Minnesota and Michigan. The results of his efforts are embodied in the Hoar Loader, as manufactured by the National Iron Works. It is shown in Figs. 14 and 15. Upon a truck is mounted a turntable, carrying the "power unit." This "unit" consists of three reversible air engines, each controlling one motion of the machine. The dipper first moves forward horizontally by the action of one engine. It is then swung into the horizontal position by the action of another. The third then rotates the turntable, until the dipper is over the tram car, when the operator trips the dipper door by hand. The operator rides the machine and handles three levers, one to each engine, in the forward or backward position. Obviously, the machine can be equipped with motors instead of air engines if desired. The machine can work in a drift 6 ft. 6 in. high by 9 ft. 0 in. wide. The movable parts are well covered and protected from dirt and water. This machine seems to be growing in favor. Entirely successful operations from the cost sheet side are reported from a number of iron mines. Though, no doubt, the machine will be improved as experience dictates, nevertheless it is past the experimental stage. Particularly good reports are heard from its operation in rock drifts where mucking is specially laborious.

All the machines thus far described are open to the criticism that they comprise constantly moving parts, such as motors, chains, elevators, and so forth, involving more or less complexity and wear. As said before, just how much weight should be given to this criticism is problematical. But there is an entirely different type of machine to which it is not applicable at all, for the movements are intermittent and obtained by means of direct-acting air cylinders. A dipper is loaded by being pushed directly into the pile. It is then swung directly upward, over and backward to a dumping position, and discharges into a tram car without the intervention of any conveying mechanism.

FIG. 12. BILLINGS & MIDDLEMISS MACHINE

The machine is capable of sufficient radial movement to enable it to cover a breast nine or ten feet wide or four and a half to five feet each side of the center line. The machine is not self-propelled, as it is argued that the idea lends itself to so light a mechanical construction that it can be readily pushed through a drift by hand and that self-propulsion involves mechanism not worth while. The radial movement, too, is accomplished by hand, but the other movements are controlled by direct-acting air cylinders. For a given amount of power expenditure there is no question that electricity is

cheaper than air. But it is argued that air is always present to operate power drills, and not in use for that purpose when loading is being done. Therefore, air is the logical power to drive the machine. The argument would seem to have considerable weight, especially in levels and in places where it is not desirable to put in electricity for haulage. Two machines of this type have been designed, the Middlemiss and the

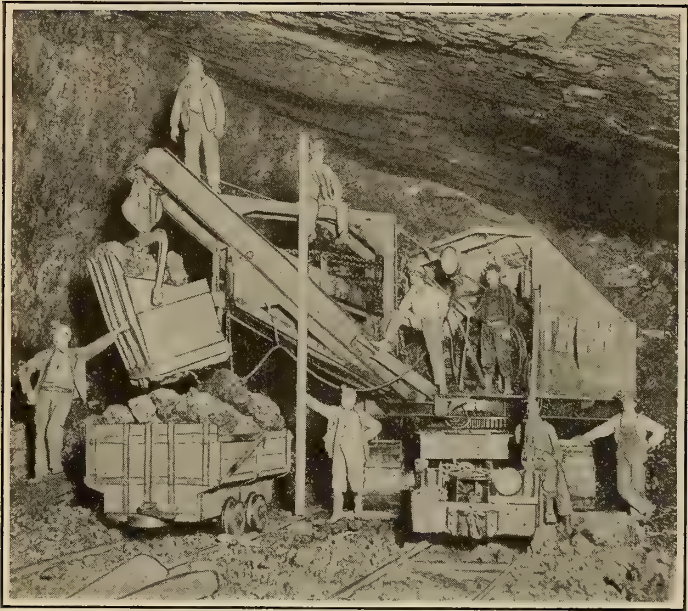


FIG. 13. THE ELECTRICALLY-DRIVEN SHOVEL UNDERGROUND

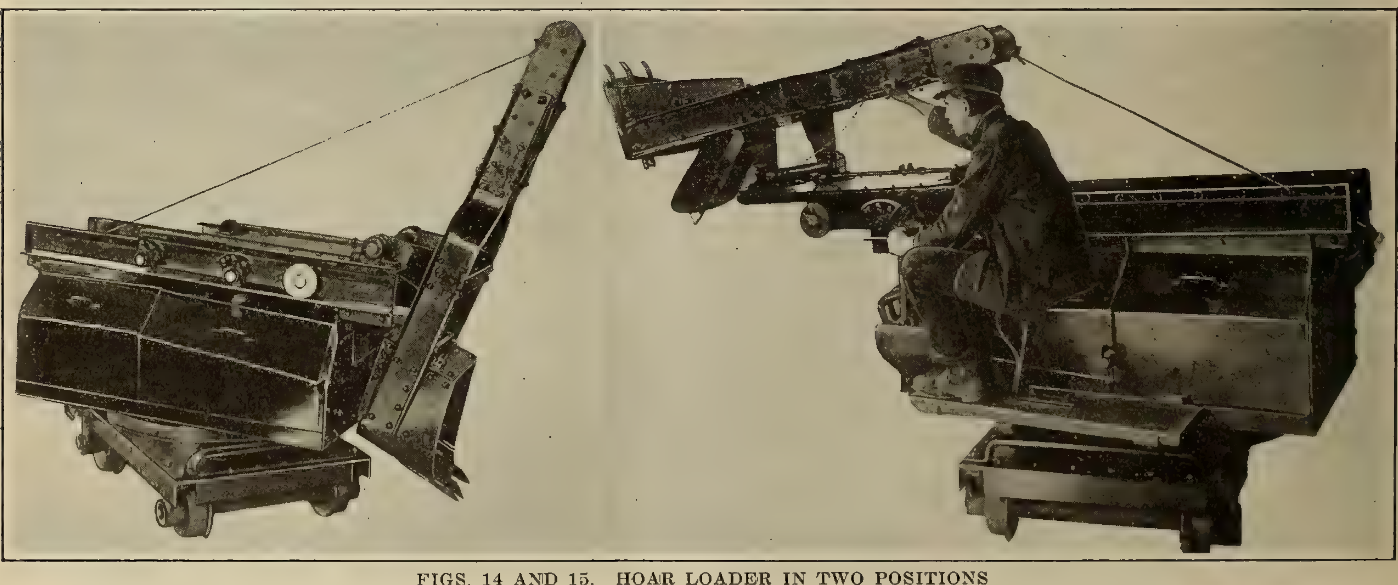
Armstrong. Though several Middlemiss machines have been built and operated underground, it is still in the development stage and has not reached commercial form. Figs. 16, 17 and 18 showed one model in three different positions.

The dipper is secured to the end of a piston rod and driven into the pile by a direct-acting air cylinder. Upon reaching the end of the stroke, the air is reversed, and the backward movement of the piston in the cylinder rotates both cylinder and dipper to the dumping position. The velocity of the dipper at the end of its backward strokes determines how far the dirt will be thrown, and this velocity is controlled by a cataract cylinder. The dipper then returns to its first position by gravity, ready to repeat the cycle. Many troubles were experienced with the one machine with which I am familiar, but they did not appear to be insurmountable and I am advised that an improved design will be tried out soon, in which it is hoped that the troubles will be overcome.

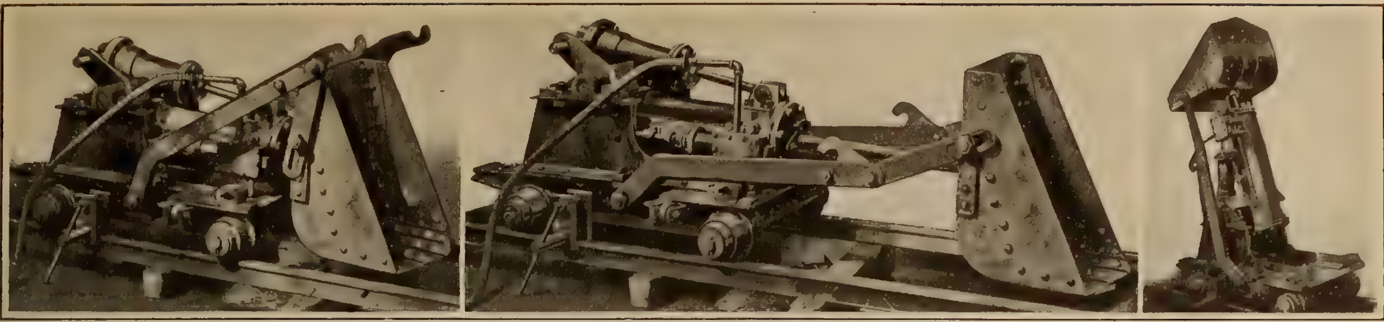
The Armstrong Loader is the result of several years' hard and persistent work of Frank Armstrong, mechanical engineer of the Penn Mining Co., and manufactured by the Lake Superior Loader Corporation. It is shown in Figs. 19 and 20. It differs widely in mechanical detail from the Middlemiss, and has little in common with it except the fundamental idea of the use of air cylinders and the movement of the dipper in a vertical plane from the digging position, over and back of the machine to the dumping position. It has one peculiar feature upon which its promoters place great stress, and that is its ability to do what they call "selective digging."

In case the dipper meets an obstacle that it cannot overcome, it does not stall but automatically raises and slides over it, continuing its full stroke. When all the dirt within reach has been shoveled, the machine is unclamped from the rail, moved forward by hand and clamped again to the rail in the new position. In order to dig across the face of a breast eleven feet wide, the machine is supported on two circular tracks, the center of which is in the rear of the machine, so that the dipper in the dumping position is always directly over the tram car. It will operate within a head-room of seven feet, and the weight is about 4,000 lb. It negotiates with perfect ease any track or curve upon which tram cars can be operated. Comparatively light in weight, simple in mechanism, with no continuously moving parts, it appears to be an extremely promising machine, especially for metal mines. In wet, sticky ore, however, trouble may be expected from the dipper's refusing to discharge. The velocity of the upward and backward movement of the dipper is capable of adjustment and control by means of the cataract cylinder. The machine is clearly beyond the experimental stage, and on a manufacturing basis, built to jigs and templets to secure exact duplication of parts. Just what its limitations are remains to be seen, for in its present form it has been upon the market only a comparatively short time, but is giving very satisfactory results in at least half a dozen metal mines.

In the December, 1918, number of *Coal Industry* there appeared an interesting and complete article entitled "Underground Coal-Loading Machinery," by E. N. Zern, in which is described the Hamilton Loader, built as long ago as 1905. It might be likened to a bucket elevator turned flatwise; and is spoken of as a "flat flight" machine. Fig 21 conveys a pretty clear idea of how an endless chain carrying scraper arms or "flights" deliver the coal upon a conveyor that in turn discharges it upon a car. The article referred to goes on to say: "The Hamilton machine in its original and improved forms was experimented with for two or three years in various coal fields. It did load coal at the rate of a ton a minute. It picked up the coal and left the floor practically clean. It would load extra large lumps, was easily handled, and fairly



FIGS. 14 AND 15. HOAR LOADER IN TWO POSITIONS



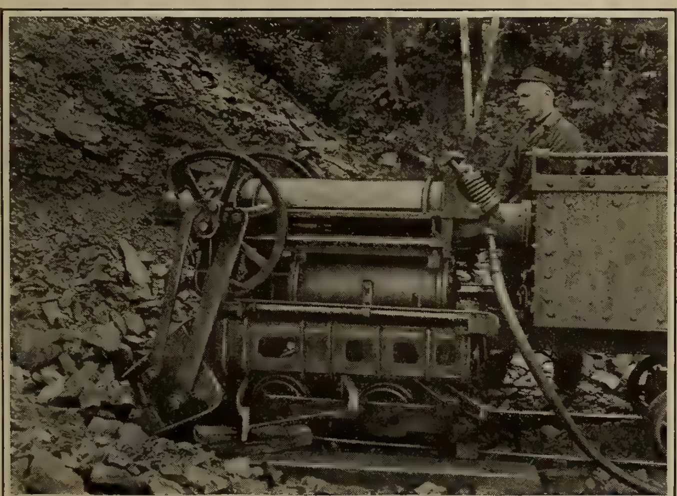
FIGS. 16, 17 AND 18. SUCCESSIVE POSITIONS OF THE MIDDLEMISS LOADER

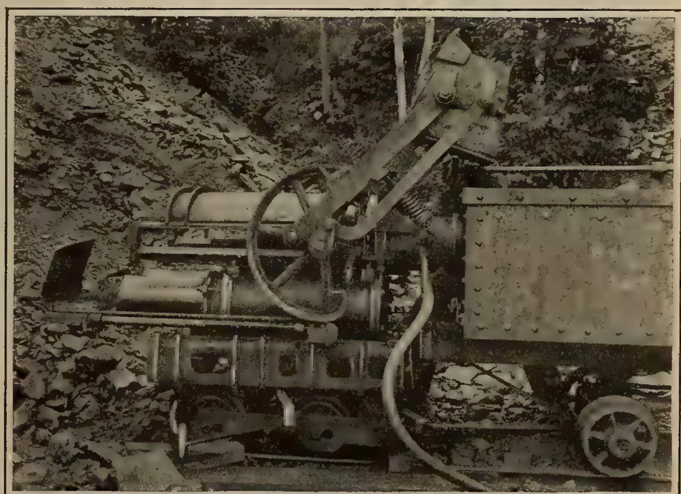
free from breakdowns. To all appearances a machine had been produced which apparently had every requirement and was capable of loading at the rate of 2,000 pounds per minute, or the equivalent of the work of ten men. But in spite of its good features it did not prove to be a success, largely owing to the fact that existing conditions in coal mines rendered it impossible to keep the machine in continuous operation. In some localities it was not permissible to shoot the coal down to the floor, as it would break too much. This necessitated the employment of extra men to pull down the coal, and they were unable to do this in such a manner as to keep the machine busy. This, together with the delays universally encountered in coal mines, left but little time for the actual loading of the coal. Further unavoidable features of the machine were its size and weight and failure to adapt itself to pillar work." The above quotation should be read carefully by too hopeful inventors, for it well illustrates the disappointments they must meet.

For the handling of dirt on the surface the road scraper or "slusher" is a very old arrangement. So, also, underground various modifications of the scraper idea have been used for many years. For a simple scraper system underground in metal mines the first requisite is a small, powerful, portable, reversible, reasonably cheap hoist that can be set up anywhere on a post or drill column and operated by anybody under any conditions. The Ingersoll-Rand Co. make the "Little Tugger" hoist which seems to fill this specification. The use of it in connection with an ordinary road scraper or "slusher" is gaining in favor in the ore mines of Minnesota and Michigan. Its use would seem to warrant the laying out of metal mines with special reference to this method of handling the ore. In Fig. 24 two "Little Tuggers" are mounted on one column, so that the scraper can be hauled back by a tail rope. So far as I know, in the iron mines of the Lake Superior district no tail rope is used, the scraper being hauled back by hand. It is a question whether the use of the tail rope is a real advantage if the haul is less than fifty feet. What appeals strongly in the scheme is its extreme simplicity. In case a straight pull from the breast to the raise in which the ore is dumped or to the car to be loaded cannot be secured, a snatch block can be used to make the turn, but the snatch block is a source of grief and trouble, and should be avoided if possible. Consequently, the mine should be laid out in advance, so that the location of slices and raises is such that the haul shall not be greater than fifty feet—twenty-five is preferable—and the pull on the rope shall be straight. In chunky ore it may be difficult to hold the handles of the scraper, especially when its nose gets under a piece embedded so tight that it cannot be moved.

In one mine where the ore was very wet the scraper was made of slats or bars, and really acted more like a rake than a scraper. It is, of course, a simple matter to make the scraper of a size and construction best adapted for the character of the material. Getting the scraper to dig into a pile and get a full load appears to be the most difficult part of the job. As a rule the two men, one on the hoist and the other on the scraper, change off. Obviously, this scheme is workable in places where it is impracticable to place a loading machine. On the sub-levels it can dispense with track laying entirely if the raises are placed properly with reference to the slices. The results attained at certain mines warrant the belief that this rejuvenation of an old idea has come to stay.

Following certain suggestions of F. E. Keese, general superintendent of the Oliver Iron Mining Co., at Ishpeming, Mich., there was tried underground an arrangement for handling a scraper which appeared to have in it possibilities, but which has not yet been worked out to a satisfactory conclusion. No photographs are available, but Fig. 23 will suffice to explain the idea. By either legs or drill columns a light channel iron is supported near the top of the drift. It carries a sheave on its front end, a "Little Tugger" on its rear end, and a trolley between. Winding up the rope by the hoist serves to drag the scraper into and up the pile of dirt, and when filled it is run backward to a point over the tram car and dumped.





FIGS. 19 AND 20. ARMSTRONG SHOVEL, DIGGING AND LOADING

It is drawn back by hand to the digging position. It was found that in case the nose of the scraper got under an immovable chunk, the man on the handles was likely to go over the top and head into the breast. In dirt that would break without chunks, and, that at the same time, was not sticky, it is probable that the arrangement could be worked to good advantage.

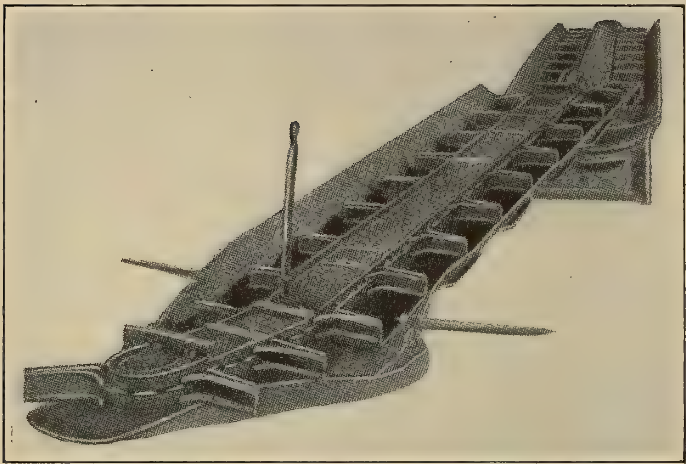


FIG. 21. IMPROVED HAMILTON LOADER

What is probably the most complete and elaborate development of the scraper idea is that known as the Evans System, the invention of Cadwalader Evans, of Pittsburgh, Pa. The Goodman Manufacturing Co. handles the invention and makes the installations. The only real novelties the system seems to possess are the thoroughness with which the details have been worked out and the peculiar "V"-shaped bottomless scraper.

Fig. 22 shows the system diagramatically in elevation. It is customary to install the layout so that it may load out a block of four rooms. A double drum hoist operates a main rope and tail rope, and by means of properly located sheaves the scraper travels the length of the room, making its own path or roadway and discharges its load into the tram car in the entry. Fig 25 gives a comprehensive idea of the scraper and of how it transports the coal. In both anthracite and bituminous coal fields it appears to be gaining in favor. A fairly full description of the arrangement will be found in the *Coal Age* for December, 1918, where the advantages of the system are given as follows:

1. It requires no track in the working place after the first crosscut is made.
2. It uses no complicated mechanism.
3. Delays are few and repairs light.
4. It simplifies the problem of replacing loaded cars with empties.
5. It can be worked in seams of any height, although more attractive to low-seam operations than high.
6. It is not affected by seams of moderate inclination.
7. In case of falls of roof, little or no injury can result, as the hoist is away from the room.
8. It is flexible and can be adapted to the drawing of pillars.

Its disadvantages would seem to be:

1. The capacity of the system is low.
2. The abrasion of the coal in the scoop as it passes over the bottom, along with the churning of the particles, causes degradation of the product.
3. The power consumption in dragging the scoop over the floor is large.

Though undoubtedly the system has been a success in coal mines, it is questionable whether in metal mines it would prove preferable to the very simple scheme described above in theoperation of which a "Little Tugger" hoist, a rope, and a road scraper are all the equipment required.

This article does not pretend to have covered the whole field. No doubt there are many machines that may have been built and tried and proved disappointments and have not come to my attention. There is also a number of machines that are in process of design. No consideration has been given here to a certain type of conveyors specially designed for use in thin coal seams, which in some cases is made to 300 feet long. In *Coal Industry* for December, 1918, will be found a reference to such machines as well as to certain loaders not discussed here.

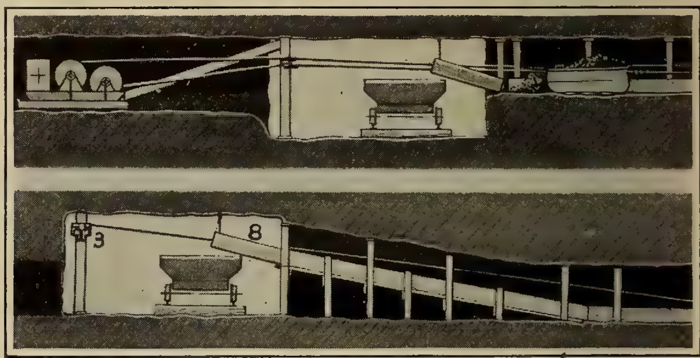


FIG. 22. DIAGRAM SHOWING EVANS SYSTEM IN ELEVATION

From all the foregoing it would appear that development is to be looked for along three general types of machines as

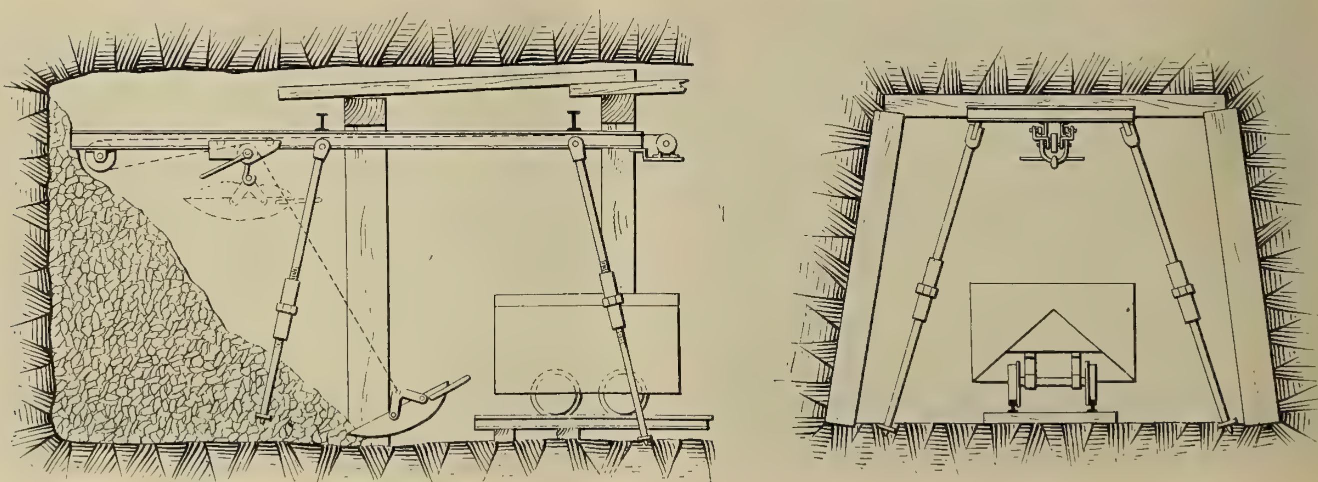


FIG. 23. OLIVER IRON MINING CO.'S SCRAPER

follows: Straight air-operated shovels that throw over in a vertical plane. The Armstrong is an example of an operative machine of this type. Small revolving power shovels, operated by air engines or electric motors. The Hoar and Thew are typical. Machines with a digging element in front, delivering upon a conveyor that discharges into a car. These are represented by the Myers-Whaley, the Halby, and the McDermott.

FIG. 24. SLUSHING UNDERGROUND USING TAIL ROPE, JOPLIN DISTRICT

It is still a question whether or not the machine should be self-propelled. That would seem to depend upon the weight of the machine and whether electric motors are available for moving the machine from place to place. Self-propulsion necessarily involves a complexity of mechanism to be avoided if possible.

Continuously moving parts and continuously moving motors would seem to be conducive to wear and loss of power. A machine of the revolving shovel type operated by direct-acting air cylinders would appear to offer possibilities, but at the same time present many mechanical difficulties. But the field is big enough, the conditions are so variable, and the demand is so insistent that there is little doubt that several types of machine will be developed, giving the mine owner a reasonably wide latitude from which to pick and choose, and reducing the labor of underground loading, with what effect upon the cost sheet remains to be seen.

TEARING STRENGTH OF PAPER.

That there is no relation between the actual tearing strength or toughness of paper and the values obtained with the commonly-used paper testers is indicated by the results of recent experiments at the Forest Products Laboratory. The method of test, employing a Schopper tensile strength tester, demonstrated that the toughness of paper can be numerically measured, but that the pop test, breaking length, percentage stretch, and number of folds give very little information about this property.

The following table gives the tearing strength of various papers in grams as determined by the laboratory method and the value obtained in the commonly-used tests:

Kind of Paper	Weight of Ream 24x36	Pop Test	Breaking Length	Stretch	Folds	Tearing Strength
	Lbs.	Lbs. per Sq. Inch	Meters	Per Cent	No.	Grams
News sheet	28	8	2,915	1.0	1	17
Steamed groundwood (brittle)	34	14	4,584	1.5	5	21
Tough kraft (soft feel)	41	44	6,670	3.6	3,020	80
Hard kraft (tinny feel)	52	38	5,320	5.0	556	73
Litho (bleached) sulphate)	44	25	4,860	2.9	248	83
Bond (all rag)	38	37	5,363	5.31	798	88
Ledger (all rag)	87	110	6,335	6.1	2,436	167

OUR OVERBUILT PETROLEUM-REFINERY CAPACITY.

Figures recently compiled by the Bureau of Mines, Department of the Interior, show that the petroleum-refinery capacity of the United States is considerably overbuilt. At the present time the refineries have a total rated capacity 50 per cent in excess of the refinable oil supplies, which will be near 80 per cent when the refineries now building are completed.

The oil runs to the refineries of the United States for the year 1919 were 361,520,153 barrels of crude oil, or, 990,466 barrels per day. In December, 1919, the refineries in operation had a daily capacity of 1,356.355 barrels per day, whereas, the daily run of crude oil to the stills was 1,046,052 barrels, indicating that they are running at only 73 per cent of their rated capacity.

It is evident that larger supplies of refinable crude oil are needed by the refineries which are now in active competition in the purchasing of crude oil in the open market. This competition for oil to keep the refineries in full operation has doubtless been one of the influences in the recent advances of crude oil in the United States. Crude oil in the Mid-

FIG. 25. EVANS SCRAPER IN USE IN A COAL MINE

Continent field, which produces some two-thirds of the refinable oil in the country, has advanced from $2.25 per barrel to $3.50 per barrel in the last few months.

A complete list of the refineries, their locations, and the daily capacities, has recently been compiled by H. F. Mason, Petroleum Economist of the Bureau, Washington, D. C.

Science and National Progress

Edited by a Committee of the National Research Council

Dr. Vernon Kellogg, Chairman, Dr. R. M. Yerkes, H. E. Howe

BUBBLES, DROPS AND GRAINS.

By Wilder D. Bancroft,

Professor of Physical Chemistry, Cornell University, and Chairman, Division of Chemistry and Chemical Technology, National Research Council.

The National Research Council is a coöperative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the natioanl strength and well-being.

Colloid chemistry is the chemistry of finely-divided masses; in other words of bubbles, drops, grains, filaments, and films. This is not an exclusive classification, because each bubble has a film around it and each film may be considered as consisting of coalesced drops or grains. On the other hand, this is rather a convenient way of looking at things, and it can be shown that bubbles, drops and grains, because of their peculiar physical properties, may be very important, both technically and in everyday life.

BUBBLES.

If we add a little oil to a large mass of water and then beat air into it, we shall form air bubbles coated with an oil film in the mass of the water. When these bubbles rise to the surface, the oil film is not sufficiently viscous to keep them from breaking and they will consequently disappear. If we have present any solid which will pass into the oil film and make it more viscous, the bubbles will not break as they reach the surface and we shall have a stiff froth, because the bubbles will practically be armor-plated. This can be accomplished, for example, by shaking up an ore consisting of a sulphide mineral and a siliceous gangue. The sulphide mineral is wetted more readily by oil than by water and consequently adheres to the oil film. The siliceous gangue is wetted more readily by water than by oil and consequently stays in the water, settling to the bottom of the tank. Since the mean density of the sulphide mineral, the oil, and the air, forming the bubble, is less than water, the bubbles rise and we get a stiff, permanent froth, which can be scraped off in any desired way, and which contains, theoretically, all of the mineral and none of the gangue. Practically it does not work out as simply as this, some of the mineral always staying in the gangue and some of the gangue being carried up with the bubbles. However, a very satisfactory concentration can be obtained in this way, and the process, which is sometimes known as the Bubbles Patent of the Minerals Separation Company, is used very extensively in this country. Some years ago it was estimated that twenty million tons of ore were concentrated by this process every year. It is probable that the amount is larger today than it was then. In the early days of this process, while it was being developed in Australia, Herbert Hoover was one of the engineers for the company.

If we blow in a great deal of air, the number of particles of the sulphide mineral on each bubble will be less, and the bubble will be correspondingly less stable. Instead of getting an armor-plated froth, we may get very fragile bubbles which will burst as soon as they reach the surface, allowing the sulphide mineral to drop back. In case this happened, there would be no concentration; but it is possible to remove the mineral just before the bubble breaks. This is known as the Callow process, the bottom of the tank being usually covered with muslin cloth, or something of that sort, through which a large amount of air can be blown in the form of fine bubbles. This differs from the strict bubbles process in that a fragile froth is obtained instead of a stable froth. On the other hand, the two have the thing in common that they both use air bubbles coated with oil as a means of floating the sulphide mineral. The amount of oil necessary is very small indeed, only a few pounds per ton of ore. There are, of course, limitations to the use of either of these processes. If the ore is not ground fine enough, the mineral particles will not stick to the oil film and will not be carried up. If the ore is ground too fine, too much of the siliceous gangue will be carried up with the mineral. The ideal method would be to grind the sulphide mineral fine and the siliceous gangue coarse; but no engineer has yet been able to accomplish this desired result.

A case in which the presence of bubbles has been very important is in the foaming of beer, because people would have refused to drink beer which had no "collar." The stability of this froth is due to viscous colloidal materials suspended in the beer, albumoses, as they are called. If these are removed, the beer does not foam, any more than we get a froth on the surface of champagne.

Bread may also be considered as an extreme case of a permanent froth, since we have air bubbles enclosed in the mass of the bread. We know that the good qualities of the wheat loaf are due very largely to the amount of gluten contained in the flour. On the other hand, there are flours which contain a high amount of gluten and which do not make a good loaf. In order to account for his, the bakers speak about strong and weak glutens. On examination, however, it seems as though all the glutens probably have the same chemical composition, in which case the difference between a strong and a weak gluten must be due either to differences in the amounts of electrolyte present, or to difference in structure. This is one of the problems which is to be studied by the recently founded Institute of Baking in Minneapolis, which is assisted by a scientific advisory committee of the National Research Council.

The characteristic property of ivory soap and some others, that they float, is due to the presence of large numbers of small bubbles in the soap. There is a report, for which I do not vouch, that a chemist once acquired great merit from the soap company by which he was employed, because he made it possible for the company to sell a carton of soap powder twice as large as that sold by the competitors at the same price. What had happened was that the soap powder was full of air bubbles, and the same amount of soap occupied double the bulk. There seems to be no reason to suppose that bubbles in soap add very much to the washing power; but they certainly have a very high advertising value.

DROPS.

Metallic sodium is prepared by passing a current through a suitable bath of fused salt, caustic soda, the molten sodium rising to the top of the bath. Metallic aluminum is made in a similar way by passing an electric current through a fused bath consisting of cryolite, alumina, and a few other substances, the molten aluminum sinking to the bottom of the bath. In both cases we find that the work must be done

within narrow temperature limits. The lower limit is, of course, that at which the bath solidifies. If the temperature is raised too much above the melting point of the bath, the bath acquires the property of scattering small drops of the molten metal all through it, and these drops, coming in contact with the other electrode, are there burned, thereby causing a great loss in current efficiency. If the caustic soda bath is heated 40° above the melting point, absolutely no yield of sodium is obtained, no matter how much current is passed through the cell. With aluminum the temperature limits are considerably wider; but it is desirable not to go more than 60° or 70° above the melting point of the bath.

In the preparation of metallic phosphorus and metallic zinc we have a very different problem in regard to drops. These two substances are distilled from the furnace and are condensed from the vapor form outside the furnace. If either of them becomes oxidized, there is formed a surface film around the drops, and we do not get a compact material. In the case of zinc, the product that is obtained, in case things go wrong, is called blue powder, and contains only 85 per cent zinc.

An emulsion consists of drops of liquid suspended in a second liquid. If we use the generic term oil to signify any liquid which is not mixable with water, we may say that we have two types of emulsions, the one being drops of oil suspended in water, and the other being drops of water suspended in oil. Milk is an emulsion of butter fat in water; butter is an emulsion of water in butter fat. Mayonnaise is an emulsion of oil in water, and so is cod liver oil. Lanolin is an emulsion of water in purified wool fat, and may contain as high as 80 per cent of water. One man has recently taken out a patent for making cheaper printing inks by diluting them with lanolin and water. This is merely producing an emulsion of water in the lanolin and oil which acts as a vehicle for the pigment of the printing inks.

It is, of course, important to know under what conditions one gets an emulsion of oil in water or of water in oil. The general belief is that this is determined by the relative amounts of oil and water, one getting an emulsion of oil in water when using relaitvely little oil, and of water in oil when using a large excess of oil. Recent investigations have shown that this is not so, and that the ordinary emulsions consist of oil, water, and a third substance which forms a film around the drops. The nature of this substance determines the type of the emulsion absolutely, and the relative amounts of oil and water have nothing to do with it. Under certain circumstances we can predict without any difficulty which type of emulsion will be formed. If we have a substance which forms what is called a colloidal solution in water and which is absorbed by oil, this substance will form a film around the oil and give us an emulsion of oil in water. If the third substance forms a colloidal solution in oil and is adsorbed by water, it will emulsify the water in the oil. Typical cases are to be found with the sodium and calcium soaps. The sodium soaps form colloidal solutions in water and do not dissolve in oil. Consequently they emulsify oil in water. The gums act in a similar manner. On the other hand, the calcium soaps form colloidal solutions in oils and not in water. Consequently they may be used to emulsify water in oil. Rosin acts in a similar manner, and in the old days ready-mixed paints used to be adulterated very largely with water, even up to 80 per cent in some cases, the water being emulsified in the linseed oil by the rosin which is always present.

A dilute emulsion is distinctly fluid; but a concentrated emulsion may behave exactly like a solid. Pickering, in England, emulsified 99 per cent of kerosene by volume in one volume of water containing soap. This gave him a stiff jelly which could be cut with a knife and the cubes would stand alone. He noticed the curious thing, that when these solid cubes were left standing in dry air, they liquefied. The reason for this was that the water in the soap films evaporated and the emulsion consequently cracked, setting free the kerosene. The mass did not become liquid because it had taken up water, but because it had lost water. The solid alcohol, which is so popular nowadays, is not an emulsion, although it does contain water. It is, more properly speaking, a jelly.

The books on lubrication tell of an experiment which bothers the authors very much. If one starts with a heavy mineral oil containing a considerable percentage of a calcium soap, and adds water to it, it was expected that the mixture would be more fluid than the original oil, because water is much more mobile than the mineral oil. Instead of that happening, however, the whole mass became solid, giving a grease instead of an oil. The reason for this is very clear to anybody who knows about emulsions. Owing to the presence of the calcium soap, the water was emulsified in the oil, and when enough water had been added a semi-solid grease was formed, just as Pickering had found with intermediate concentrations of kerosene in water.

The pharmacists make a great use of emulsions, and the books on pharmacy are filled with elaborate descriptions as to the methods of making them. The usual way is to dissolve the gum which is used as an emulsifying medium in the water, place this in a mortar, and then add the oil a little at a time with continuous stirring. The chemist is trained to use vessels which seem to stand in some proportion to the amount of substance that he is using. On the other hand, the pharmacists lay down the rule that one must use a very large mortar, the more nearly the size of a bath tub the better. They are also very particular about the way that the mixture shall be stirred. If one starts stirring to the right, one must continue stirring to the right, or no emulsion will be formed. Some books go so far as to say that a left-handed man cannot make an emulsion, which seems a bit absurd. Many of the precautions given by the pharmacists seem foolish; but, on the whole, empirical rules, which have stood the test of years, usually prove to have some foundation, although the reasons given for them may be entirely wrong. This is the case with emulsion-making.

When the chemists started to make emulsions, they said that it ought to be much simpler to add all the oil at once and to shake by machine instead of stirring by hand. This did work well for the dilute emulsions, but it was found that no amount of shaking would give a very concentrated emulsion. At first the chemist thought that this was due to inefficient shaking, and he devised a much better shaking machine, which, however, gave practically the same results. It was then found that if one put the mixture in a bottle, shook it by hand for a few times, allowed it to settle, and then shook again, this intermittent shaking gave results which could not be obtained by doing a thousand times as much work with a shaking machine. It was then clear that one reason why the pharmacist had added the oil a little at a time was because this was equivalent to intermittent stirring, for he stopped between times. Since it is necessary to break the oil up into drops or thin films in order to get a good emulsion, the pharmacist had used a mortar which appeared much too large, because he then spread the mixture over the whole surface of the water, thereby giving him a thin film and consequently a rapid emulsification. We now know the reasons for the pharmacist acting as he did, and we can also get the same results with much less effort.

This experience threw some light on the preparation of mayonnaise. As everybody knows, the making of mayonnaise is a thing which the average housewife approaches with fear and trembling. Everything has to be just so or else the mayonnaise will not come out successfully. Since mayonnaise is essentially an emulsion of oil in water with white of egg as the emulsifying agent, it ought to behave like any other emulsion. The experts in the Departments of Home Economics have no difficulties with mayonnaise. They can add the ingredients in any order; they can add them all at once or in separate portions; they can add them hot or cold; and I know one expert who could actually make a mayonnaise

using the yolk of a hard-boiled egg instead of the white of egg. It was not a very pretty mayonnaise, because it was distinctly granular and looked like the end of a needle when seen under the microscope; but there was no question about its being mayonnaise. On the other hand, these same experts are not able to tell their pupils how to make mayonnaise successfully every time. This means that there is something or other which they do unconsciously and which consequently they cannot tell to their pupils. The experiments with the intermittent shaking seem to give a clue to this difficulty. The expert is so sure of the result that she probably works leisurely and without being hurried or flurried. On the other hand, the person who is not an expert and who is uncertain about the outcome, probably goes at the thing so vigorously as to defeat her own object in many cases. This has not been tested as yet; but I have been told by one expert that she had found that if the materials were beaten well together and then allowed to stand for a moment or two, a couple of swishes would make the mayonnaise. Instead of the conclusion of the pharmacists that a left-handed man cannot make an emulsion, it would probably be more correct to say that a nervous woman cannot make mayonnaise.

The behavior of sodium and calcium salts in emulsion-making throws light on some problems in physiology which had bothered people a great deal. Jacques Loeb and his pupils had found that certain marine organisms died when put into fresh water. This was not surprising, and the explanation that was offered was that the water passed into the organisms, causing them to swell and burst, which was of course fatal. This osmotic pressure explanation, as it was called, came to grief because it was found that the organisms died quite as rapidly if they were put in a sodium chloride or a calcium chloride solution having the same osmotic pressure as sea water. This could not be accounted for on the basis of osmotic pressure. On the other hand, the organisms which died in pure sodium chloride solutions or in pure calcium chloride solutions lived when they were placed in a solution having a definite ratio of sodium chloride to calcium chloride. The explanation has been given by Clowes. If we consider protoplasm as consisting of lipoid materials, which we will call oil, and water, we shall have an emulsion of oil in water in presence of sodium salts, and an emulsion of water in oil in presence of calcium salts. When the sodium and calcium salts are present in a defiinte ratio, there will be a balancing between these two types of emulsions, and it may well be that this critical state is the one which is conducive to life and growth. As a matter of fact, Clowes found that the ratio of sodium and calcium salts necessary to produce a balancing between the two types of emulsions when working with oil, water and soap, was practically the same as that found in sea water. This shows a very close connection between the two sets of phenomena. Osterhout, at Harvard, has shown that the specific electric conductivity of certain tissues is increased by addition of sodium salts and decreased by the addition of calcium salts. If the hypothetical emulsion changed to one of oil in water, the conductivity should increase, and it should decrease if the emulsion changed to one of water in oil. Clowes has succeeded in duplicating Osterhout's results by impregnating filter paper with an emulsion of oil, water and soap, to which he afterwards added sodium and calcium salts.

GRAINS.

If we take spherical shot and place them in a box so that they are packed uniformly, mathematics shows that so long as the shot are uniform, we get the same amount of metal in the box regardless of the side of the shot. If we add shot of two different sizes, the fine shot goes into the voids left by the coarse ones and we get more shot in the box. If we work with very fine powders, we get a different result, because the finest particles do not pass into the voids left by the coarser powders, but coat the coarser powders. A well-known case of this is sugar and blue-berries. C. G. Fink, who was then with the Harrison Works of the General Electric Company, and who is now Director of Research for the Chile Exploration Company, took equal mixtures of metallic tungsten, which forms a black powder conducting electricity, and of thoria, which form a white powder which does not conduct electricity. If the thoria powder was relatively fine and the tungsten powder relatively coarse, the thoria coated the tungsten and Fink obtained a white powder which did not conduct electricity. If the tungsten was relatively fine and the thoria powder relatively coarse, he obtained a black powder which conducted electricity.

If one mixes a coarse white powder with a very fine red powder, the red powder will coat the white grains and the mass will look almost as red as though it were made of the red powder alone. If the red powder is relatively coarse and the white powder relatively fine, the white powder will coat the red and will mask its color practically completely. This has been known empirically to the paint-makers for a long time, though they have not known the reason for their practice. They are in the habit of adding ground barytes, which is a white powder, as a filler for red paints. They say that precipitated barium sulphate cannot be used. Since barytes is a natural, and consequently impure, barium sulphate, this statement seems to the chemist at first quite inexplicable. The explanation is a very simple one. The precipitated barium sulphate is very much finer than the ground barytes and consequently not so much can be added without interfering with the red color of the pigment.

A flat surface may be considered as a piece of a grain of infinite size. If we look at the reagent bottles in a chemical laboratory, we shall find that some of those which contain solid powders are dirty on the inside. In all cases those will prove to be the ones containing the finest powders, which are able to stick to the glass surface. The same principle of a fine powder sticking to a coarse powder or to a surface is involved when we write with pencil on paper or with chalk on a black board, the only difference being that the paper surface and the black board surface are fairly rough, so that they help to rub off pieces of the pencil or of the chalk. If the piece of chalk which breaks off is too coarse, it will not stick to the black board but falls to the ground.

The ceramic industry depends on the behavior of grains. If we take the clay and burn it, the grains sinter together and we get a porous plate, a brick, or earthenware, as the case may be. If we put in some fusible material, we get the various grades of china and of porcelain. In fact, porcelain may be considered essentially as a silica glass made translucent by grains of the aluminum silicate known as sillimanite. If the whole mass fuses so that the grains disappear. we have a glass. The opaque enamels are glasses in which are suspended white grains of tin oxide, zirconia, or other suitable material. In the case of cement, the clinker is ground to a powder and it is the resulting grains which are used for building purposes.

Porous charcoal is a granular material which came into prominence during the war, because of its use in gas-masks to stop toxic gases. The use of other porous materials, such as pulverulent platinum and nickel, is very important both in times of peace and war, on account of their power to accelerate reactions. The manufacturer of sulphuric acid, ammonia, nitric acid, and hardened oils illustrates the importance of such granular materials, and the list could be extended indefinitely.

Smoke consists of solid particles, usually carbonaceous, suspended in the air; but we also include under the general heading of smoke the solid particles from the fumes of smelters. The Cottrell electrical process enables us to remove the solid and liquid particles from these fumes, and this has proved very effective in California, where people insisted on making cement in the midst of orange groves. The dust thus recovered at cement plants bids fair to be an important

source of potash. While the Cottrell process takes the solid and liquid particles out of the smelter fumes, it does not solve the problem completely so far as the farmers are concerned, because it will not remove the gaseous sulphur dioxide which also damages the crops. At the Washoe smelter of the Anaconda Company, the Cottrell process involves the use of 111 miles of chains merely to make one set of electrodes, the other set being composed of huge plates. This means a possible recovery of 35 tons of arsenic per day.

The flames of burning fires, candles, lamps, and gas jets owe their luminescence to the presence of incandescent particles of carbonaceous material. This can be shown by putting a chilled dish down into the flame, in which case one gets a deposit of soot on the cooled surface. When we put different salts into the gas flame of a bunsen burner, we may get different colors, yellow with sodium, blue or green with copper, and red with lithium. Since the temperatures of these films are, or may be, all the same, the difference in the colors cannot be a question of temperature and must therefore be due to a chemical reaction. It seems probable therefore that with a copper salt, for instance, we have a salt breaking up at the high temperatures into metallic copper, and that the color is due to the alternating formation and decomposition of a copper salt. In order to prove this, one must show that metallic copper is really present in the flame. This can be done easily in a way quite similar to that used for showing the presence of soot in the ordinary flame. If we let cold water run through a porcelain tube and then place this porcelain tube in a flame colored green by a copper salt, we shall get a beautiful deposit of metallic copper upon the porcelain. Similar results can be obtained with salts of the other metals. In some cases, as with tungsten salts, no metal can be obtained when using the bunsen burner, because the temperature is not high enough. By putting these salts in the oxyhydrogen flame, it is possible to obtain a deposit of metallic tungsten on the porcelain tube. Of course, this suggests a wonderful possibility in perpetual motion. All one has to do is to burn coal and air to carbon dioxide, heat the carbon dioxide to a temperature at which it will break down to carbon and oxygen, collect the two and burn them over again. This could actually be done, but of course not economically.

In the photographic plate we have grains of silver bromide dispersed in a gelatine film. It is the gelatine adsorbed by the grains of silver bromide which determines the speed of the plate; it is the silver adsorbed by the grains of silver bromide which gives rise to the latent image; and it is the reducing agent or developer adsorbed by the latent image which makes the picture.

Reference has been made to the fact that a film may be considered as made up of coalesced grains or drops. These may also be very important in many cases. Aluminum should be oxidized very readily and should, theoretically, be of no value for everyday use. As a matter of fact, there is formed on the surface a film which protects the aluminum from further chemical action. The same thing occurs with nickel. If iron rust formed a coherent film which protected the metal, rust would not be a serious phenomenon with iron any more than it is with aluminum or nickel.

One of the important things in chemistry is to make use of the waste products. As has been stated, blue powder consists of 85 per cent zinc. By heating this in presence of iron, some of the zinc sublimes over and condenses on the iron, giving a galvanized surface. The process is known as sherardizing, from the man who invented it. It has become so important that the supply of blue powder is not sufficient for the needs, and it is necessary to make a zinc powder from good zinc in order to keep pace with the demand.

When we put oil on a road, the oil forms films around the grains of the road material and binds them together. We do the same thing in making foundry cores, except that there we use an oil-water emulsion instead of oil alone. If the liquid film is of a suitable thickness, the mass becomes plastic. In making fondant, the two important things are to heat the mixture so as to change just enough of the sugar over into a non-crystallizable form, and to stir so rapidly that the sugar which does crystallize comes down in very fine grains, coated with a syrupy film due to the invert sugar. That gives us a plastic mass having the desired properties. When pigments are mixed with linseed oil, we get a plastic mass, in which the linseed oil finally dries to a solid material, which holds the pigment to the material painted and which forms a protecting film over the surface of the material. In the case of glue and other adhesives, we have a liquid film which gradually solidifies and which is used to hold the two surfaces together. In the case of varnishes and lacquers, we have a liquid film applied to a surface and which dries finally to a solid film, which is both protective and decorative.

These illustrations are probably sufficient to show the importance of bubbles, drops and grains, which are the subjects of study of colloid chemistry. It is not too much to say that colloid chemistry is the chemistry of everyday life.

GOVERNMENT MAPS.

By Edward B. Matthews,
Professor Mineralogy and Petrography, Johns Hopkins University, and Chairman, Division of Geology and Geography, National Research Council.

The bringing together of men from all parts of the country at Plattsburg, and later in the various cantonments and officer training camps, awakened in them a new interest in geography and in the study of maps, which had lain dormant or become atrophied since boyhood days. More than one officer-in-embryo, lost in the woods with a small detachment, found that he could work his way out by the map which he had in his equipment. At first he regarded the curved brown lines as a nuisance detracting from the clearness of the map, but soon he learned to prize them as a picture of the hills and valleys, and a prophet of the roughness of his coming "hike." To many this was the first introduction to the topographic map of the United States. Some few had learned of these maps in automobiling, but practically none of the boys, except a few collegians knew anything of how the maps are made or of the work which the Government is doing to produce and supply accurate topographic maps of its vast domain.

The topographic branch of the U. S. Geological Survey was organized about thirty years ago through the consolidation of previous organizations for surveying the territory west of the 100th meridian—the Rocky Mountains, and the regions westward to the Pacific Coast. The initial aim was the preparation of a geological map of the public lands to assist in the development of the natural resources of this vast and sparsely settled region. But the need of good maps for all the country immediately led to an extension of the service to include the whole nation. The present aim of the geological survey is to cover the United States with a general utility map, supplementing this with special purpose surveys on larger scales when such are necessary. In spite of thirty years of activity only 43 per cent of the area of the United States has yet been covered by standard topographic maps and a fifth of these now need revision. It is estimated that it will require nearly fifty million dollars and fifteen to twenty years to complete the map, though the work can be done in twelve years if Congress makes the necessary appropriations.

Besides the Geological Survey, there are thirteen other Federal map-making organizations with more or less complete technical staffs and separate appropriations, as follows:

1. *The U. S. Coast and Geodetic Survey* prepares coast charts and larger-scale harbor charts which give the depths of the water, and the shorelines and topography as far inland as can be seen from the water. It also supplies the geometrical network and basic vertical control on which the local maps of the Geological Survey are constructed.

2. *The Hydrographic Office of the Navy Department* makes original surveys and publishes maps, but its work is entirely

outside the continental limits of the United States. When it needs shore topography as an aid to navigation, the maps are based on pre-existing work or on original surveys.

3. *The Corps of Engineers, U. S. A.* prepares detailed topographic maps with military information in the vicinity of strategic points where military operations are probable. It also prepares the special maps necessary for practically all Federal improvement projects such as river control, canals, etc. Many of these maps contain confidential military information.

4. *The Mississippi River Commission* prepares maps of special types dealing with the hydrography of the river and the topography along the shores. This Commission publishes its own maps and issues pamphlets giving information as to its benchmarks, changes in the bed of the river, and other features of value to river pilots.

5. *The U. S. Lake Survey* publishes navigation charts of the Great Lakes, the New York State Canals and the Lake of the Woods.

6. *International Boundary Commission.* This Commission is charged with the survey and marking of the International boundary between Canada and the United States from the Arctic Ocean to Cape Muzon and from the Atlantic to the Pacific, excepting through the Great Lakes, the St. Lawrence and connecting waters. According to the treaties the lines must be described in reliable maps, and it has therefore been necessary to make a topographic survey of a strip a mile or so in width all along these lengthy lines. The published maps will conform as far as possible with those made by the Geological Survey.

7. *The Forest Service* uses the standard topographic map when possible, but it makes surveys and maps for its own purpose as occasion requires. These conform in general to the standard topographic map when based on original surveys, but often maps are compiled from such meagre information as may be available. The scale of its maps are just a trifle different from the standard topographic map.

8. *The Bureau of Soils* uses existing maps whenever possible, but to meet the demands of farmers' organizations and Congressional requests in all the states of the Union it is often forced to use any map available, such as Land Office maps or local county atlas sheets. Very frequently it makes traverse maps of its own. The scales of the maps and their accuracy, therefore, vary widely at times from the standard topographic maps. The unit of publication is usually some minor political subdivision, so that the sheets vary in size or scale.

9. *The Reclamation Service* makes a wide variety of maps to cover its needs in the construction of irrigation and drainage works and in the classification of the lands for irrigation purposes. These maps vary from preliminary reconnaissance surveys to refined surveys for reservoir sites, and therefore differ widely in scale and accuracy.

10. *The General Land Office* is primarily interested in subdivisions showing public and civil land boundaries, especially in the Public Lands and Indian Reservations. The character and scales of the maps vary widely. Some are based on actual surveys while others are merely compilations from county or commercial maps.

11. *The Bureau of Indian Affairs* uses whatever suitable maps are available, and where these do not exist makes maps based on its own surveys. These differ widely in scale and character.

12. *The Bureau of Public Roads* is a map-using rather than a map-making agency, but in carrying out the program of the Federal Aid for roads project it will coöperate with other agencies in the preparation of State road maps. Moreover, during the surveys of roads constructed under its supervision much information in the way of traverses and levels will be gathered which will be of great value to engineers interested in public works.

13. *The Topographic Branch of the Postoffice Department.* Although this organization does not maintain surveying parties, it sends numerous inspectors over the country and compiles and publishes Post Route maps, Rural Delivery County maps, and maps of local centers.

Such a multiplicity of government agencies doing much the same sort of work in surveying and publishing maps leads inevitably to excessive costs and confusion both to the Federal and non-Federal users of maps. Every industry, art or science, governmental or otherwise, which requires a knowledge of the lay of the land is dependent on suitable maps, and detailed work requires specific information regarding facts determined during the making of such maps. An immense wealth of such information has been collected by the several map-making agencies, but experiences during the war have emphasized the fact that few officials and fewer civilians know where to turn to get the specific information desired at the moment. To overcome the lost efficiency, due to overlapping among the Federal agencies, and to reduce the confusion as to where information already secured might be obtained, the President, by Executive Order of August 27, 1919, convened an Interdepartmental Conference of all the Federal Map-making Organizations. This conference, after several sessions, filed a report including the following recommendations:

1. That a permanent Board of Surveys and Maps, composed of one member from each of the Government organizations represented in the conference, be appointed to act as an advisory body on all questions relating to surveys and maps.

2. That a central information office be established in one of the Government map-making agencies, preferably in the U. S. Geological Survey, for the purpose of collecting, classifying and furnishing information concerning all maps and survey data available in the several Government organizations and from other sources.

It was further proposed that the new Board should confer with those interested in the making and using of maps and thereby establish closer coöperation between the work of these outside agencies and that of the Government. In order to make such coöperation effective, representatives of the Engineering Council, American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, American Association of State Geologists, American Association of State Highway Officials, The National Research Council, the Association of American Geographers, The American Geographical Society, and the Geological Society of America met at the rooms of the National Research Council and organized under the chairmanship of Professor Edward B. Mathews, Chairman of the Division of Geology and Geography of the National Research Council.

After several subsequent conferences and correspondence with map publishers, educational institutions and map-users, this committee has prepared a report with recommendations which will be presented to the permanent Board of Surveys and Maps which was established by Executive Order on December 30, 1919, "to coördinate the activities of the various map-making agencies of the Executive Departments of the Government, to standardize results, and to avoid unnecessary duplication of work."

In pursuance of this Executive Order the Board has met, organized, and established its methods of procedure. It purposes to establish at an early date a map information office in the Interior Department Building, Washington, D. C., which will collect and catalogue, as rapidly as possible, information concerning maps, surveys and survey data, not only of the Federal Government, but of other Governmental and private agencies. The members of the new Board desire that this information office shall be of service not only to the Federal Departments and Bureaus, but to the general public. The Board would welcome suggestions concerning the means whereby this office can be of most public value and hopes that the fullest use will be made of its facilities. Such suggestions may be sent direct or transmitted through the committee representing outside agencies mentioned above.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

RADIO RESEARCH AND CO-OPERATION WITH UNIVERSITIES.

THE radio laboratory of the Bureau of Standards is coöperating with various university laboratories in research work. The service which the Bureau of Standards laboratory can render to the universities includes the furnishing of research suggestions, technical data and publications, advice on particular technical problems, and in the standardization of instruments and apparatus for the university laboratories. A number of the universities have been supplied with information and suggestions of assistance in the prosecution of scientific research work upon such subjects as radiotelephony, methods of radio measurement study of electron tubes, and the development of circuits for particular purposes in the production and detection of radio currents. Information on radio laboratory equipment has likewise been supplied. Another way in which coöperation is furthered is by assistance in the publication of technical results by reading and criticizing papers and books prepared by research workers.

Radio instruction in a number of the universities has been facilitated by the use of two of the publications prepared by the Bureau's laboratory, "The Principles Underlying Radio Communication" and "Radio Instruments and Measurements." The first is an elementary non-mathematical introduction to electricity and radio, and the second is a fairly advanced text on radio measurements and theory.

One of the investigations now in progress at the Bureau's laboratory is adapted to direct coöperation in the experimental work between the Bureau and the universities. This is the study of radio waves and their behavior. Measurements of radio wave intensity and direction carried on over a long period of time will make it possible to learn much about the way in which waves function and will make possible rapid advaices in the control and utilization of the waves in radio communication for commercial purposes. It is found that the waves exhibit great variations with time, weather conditions, and type of ground travelled over. From this work it will be possible to calculate the strength of the signal which will be obtained at a distant station when the current used at the sending station and the distance and other factors are known. With this end in view, signals are being sent out from the Bureau's laboratory and careful measurements made upon these signals at a distant univesity laboratory. University workers who desire to coöperate in this research will be assisted by the Bureau, and arrangements will be made to standardize the aparatus which they use for measurement.

The following radio laboratory reports in connection with radio research are available:

- Suggestions for Radio Research;
- Fees for testing Radio Apparatus;
- List of Manufacturers of Radio Apparatus;
- List of Manufacturers of Electron Tubes.

A list of desirable research problems on radio waves is given in Bureau of Standards Scientific Paper No. 354, "Principles of Radio Transmission and Reception with Antenna and Coil Aerials." A suggested list of laboratory experiments for radio training sources is given on pages 342-349 of the publication mentioned above, "The Principles Underlying Radio Communication."

RADIO SUBJECT CLASSIFICATION.

One of the important duties of modern scientific research organizations is that of keeping in touch with the literature of the subjects studied. In its work as a clearing-house of information in radio science and engineering, the Bureau of Standards radio laboratory has felt the need for a systematic scheme of classification of subjects. Such a classification is needed for references to radio publications, books, drawings, reports, miscellaneous data, and information. A tentative scheme of classification has been prepared, grouping subjects of radio interest under the following principal headings: Radio Wave Phenomena; Antennas; Electron Tubes; Radio Measurements; Properties of Materials; Radio Theory; Radio Research; Radio Instruction; Miscellaneous Radio Apparatus and Methods; Radiocommunication and Applications; Radio Miscellaneous; Electrical Subjects Related to Radio, and Miscellaneous.

It is desired to make this list as complete, comprehensive, and usable as possible, and with this end in view, the Bureau of Standards will be glad to send a copy of the complete classification to any persons interested, with the object of securing suggestions as to its possible improvement.

PHYSICAL CONSTANTS OF INTEREST TO THE REFRIGERATING INDUSTRIES.

Of the numerous investigations on physical constants of materials which are being conducted at the Bureau of Standards, a number that are of particular interest to the refrigerating industries have recently been completed and prepared for publication. The physical properties of ammonia are of greater interest to the refrigerating industries than those of any other material since ammonia is the medium used in by far the largest number of plants.

Two recent papers deal with the vapor pressure of saturated ammonia and with the densities of the liquid and of the saturated vapor. In connection with the determination of the vapor pressures, use was made of a pressure gage of unique construction, which proves to be very accurate. A paper dealing with the specific heats of sodium chloride solutions which are used in making of artificial ice has also been completed.

These papers will be published in the course of the next few months in the *Journal of the American Society of Refrigerating Engineers*, which has its headquarters at 154 Nassau Street, New York City. A more detailed account will be published later by the Bureau.

NEW CHEMICAL PUBLICATIONS.

Several publications have recently been issued by the Chemistry Division of the Bureau, and some articles by members of the Bureau's staff have appeared in scientific journals which are of interest to all those engaged in chemical work.

A list of these, with short abstracts, giving the salient facts contained in each pamphlet, is as follows:

(1) A New Hexabromide Test for Linseed Oil, by L. L. Steele and F. M. Washburn. Published in the *Journal of Industrial and Engineering Chemistry*, January, 1920.

"Various published methods for the determination of the hexabromide yield of linseed oils have been investigated, especially the Eibner method. An explanation is given of the observed fact that this method does not yield concordant results. Experimental work leading to the development of a new hexabromide method is given, the main features of which are the addition of bromine to the fatty acids of linseed oil in a solvent in which the resulting hexabromide is soluble, the addition of a reagent to remove excess bromine, the removal of the solvent by evaporation, and the isolation of the hexabromide free from contaminating bromides by thorough washing with absolute ether saturated with hexabromide. A table of

results obtained so far indicate that the hexabromide yield of pure raw linseed oil is a more constant value than the iodine number. Results are also given on mixtures of linseed and other oils, such as soya bean oil, which indicate that it may be possible to estimate quantitatively adulteration of linseed oil with other oils which give a low hexabromide yield."

(2) Specification for Basic Carbonate White Lead, Bureau of Standards Circular No. 84.

(3) Constant Temperature Still Head for Light Oil Fractionation, by F. M. Washburn. Published as Technologic Paper No. 140, and in the *Journal of Industrial and Engineering Chemistry*, January, 1920.

"The paper gives a brief review of the three types of methods generally in use for the fractionation of light oil and describes an apparatus which is an improvement on the dephlegmator of the Wilson and Roberts still. The use of a constant-temperature still head, consisting of a spiral of iron pipe immersed in an oil-bath, electrically heated, and regulated by means of a thermostat, makes it possible to condense out practically all of the constituents having a higher boiling point than the fraction desired. The vapors pass first through a Hempel column and then through the still head. The construction, manipulation, and accuracy of the apparatus are given in detail, together with its value and applicability to the benzol industry."

(4) Detection and Determination of Glue in Rubber Goods, by S. W. Epstein and W. E. Lange. Published in *Rubber Age* and to appear as a technologic paper.

"The authors investigated the various procedures which suggested themselves for the detection and determination of glue in vulcanized rubber. It was found that the only quantitative procedure to determine the glue content was the Kjeldahl nitrogen determination. This was found to be satisfactory with certain variations which are given in the paper.

"The authors discovered that cresol dissolved glue even more readily than water, and that the resulting solution precipitated 70 per cent of its glue content on the addtion of petroleum ether. Since rubber remains in cresol solution when petroleum ether is added, there is here a means of separating glue from rubber. These behaviors are made use of by the authors in their qualitative method. Details by which this separation is carried out are presented by the authors in their recommended procedure for the detection of glue in rubber. Results are given showing that as little as 0.9 per cent of glue can be detected. From the results of many experiments, the author's point out that the procedure is reliable in every case, and that no substances will interfere with the test."

In conclusion the authors make the following statements:

"1. A method is presented which will detect as little as 0.9 per cent of glue in a rubber "mixing." It has been found by experiment, that no substance other than glue will answer to this test when carried out as directed. The procedure is reliable and convenient.

"2. When glue is present in a rubber sample its quantity is arrived at by determining the nitrogen content by means of the Kjeldahl procedure and calculating this to glue. We have been able to find no other satisfactoy quantative method which would give the correct percentage of glue."

EFFECT OF STRIAE IN OPTICAL INSTRUMENTS ON RESOLUTION.

As a result of some of the work performed by the Bureau of Standards on optical instruments, it was found that a certain amount of striae might be permitted in the lens systems of such instruments without having any bad effect on the operation of the complete apparatus. Work is now nearing completion on the design of a proper resolution chart which is preliminary to the investigation of the effect of striae in an optical system on its resolution. A report on this preliminary work is being prepared which presents curves showing the relation between the resolution of a telescope and the intensity of the illumination of the test chart. Other curves plot the relation of the resolution to the degree of contrast between the background of the chart and the lines ruled thereon. These curves were obtained by using different types of charts, such as one ruled with a 1 mm. line having sharp edges, another with two or more narrower lines, etc. The results so far obtained indicate that considerable assistance may soon be extended to the manufacturer with whom rests the decision as to how much striae he may permit in the prisms and lenses of his optical systems.

CAMERA FOR MEASURING THE INTERIOR OF RIFLE BARRELS.

In connection with the determination of the amount of erosion within gun barrels after certain amounts of firing, the Bureau has been called upon to construct a camera which will make a panoramic view of the inside of the barrel. Work on this camera is progressing rapidly. The lenses have been designed and the work on other parts is nearly completed. If the camera proves to be a success, it will be possible to study the interior condition of a small gun barrel at any period of its life without the necessity of sawing through the barrel lengthwise, which was the only means known before this camera was suggested. The investigation of the interior of the gun can then be carried on without destroying the barrel.

A MINING GLOSSARY.

The mining industry has long felt the need for a comprehensive, thorough and complete glossary of the terms used in its various branches. This requirement has been met recently by Albert H. Fay, Mining Engineer, U. S. Bureau of Mines, author of Bulletin 95, "A Glossary of the Mining and Mineral Industry," which contains about 20,000 terms and nearly 30,000 definitions covering all phases of coal and metal mining, quarrying, metallurgical plants, coke-ovens, oil and gas wells, geology and mineralogy.

The words are arranged alphabetically in true dictionary style, there being no industrial grouping. Only one glance is necessary, therefore, to find any desired term. The type and style of composition are such as to render it easy to find the word, and read the definition.

A cursory glance through the 754 pages reveals years of research, and painstaking study in preparing, assembling and coördinating the definitions from many and varied sources, and inserting proper cross references. The scope of the work includes all English-speaking countries, as well as much that is Latin-American. Usually the name of the State, province, or country is given showing where the more provincial terms originated or where they are extensively used.

In most cases the name of the author quoted is given in parenthesis at the end of the definition, thus making it possible to trace the term back to the publication in which it previously was defined. The use of the author's name has possibly resulted in some variation of syntax, as in general, too much alteration would not be permissible, and still quote the definition. About 150 authors are quoted as indicated by the list of publications cited, 100 of which publications contained glossaries relating to some phase of the mining industry.

The glossary contains many words that are more or less obsolete and this feature may be considered an advantage rather than a detriment, as the older literature contains many terms that are not now current. The scientist engaged in research work is always glad to know where the older terms are properly defined.

Some of the terms that have figured in mining litigation, as for example, "abandonment and forfeiture," "apex," "fissure," "lode," "vein," and scores of others, have been given special attention, a number of similar but slightly different interpretations being given and many court cases cited wherein the decisions were rendered. These court citations in addition to definitions from other sources add much to the value of the publication from a legal standpoint.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

PHOTOGRAPHIC RESEARCH.

The British Photgraphic Research Association has published some of the results of its work; one contribution being upon "The Fundamental Law for the True Photographic Rendering of Contrast," and another deals with "Contrast and Exposure in X-ray Photographs Through Metals." In this last article, the point is made that in photographing through a centimeter or more of metal the photographic effect is almost entirely due to the hardest rays, and the contrast obtained depends only on the quality of these rays and not on the absolute thickness of the metal. Also the softer these hardest rays are, the greater is the contrast. This may at first sight appear to be opposed to experience, but the explanation is as follows:

Suppose we photographed a piece of iron 1 cm. thick containing a bubble of half a millimeter diameter, we can easily obtain a good contrast on the photograph. Now if you want to photograph a bubble of the same diameter in a piece of iron 6 centimeters thick, we can do so and obtain the same amount of contrast if we use the same voltage on the X-ray tube but increase the exposure many thousand times. In practicing with a piece of iron 6 centimeters thick we use a harder radiation to get a reasonably short exposure, and consequently the contrast obtained is very much less.

These observations have a bearing upon work now in progress here on the use of X-rays as a means for detecting defects in metals, leading to a process which can be employed in inspection without destruction of the sample.

The Association has also published a short discussion on "The Properties of an Emulsion to give the best result in a process plate." As much as possible of the silver bromide should be in grains of the same size, and the presence of a small number of grains larger than the majority would have a worse effect than the presence of the same number of smaller grains, because the larger grains give rise to more silver on development. The absolute size of the grain does not seem to matter very much as long as they are all of the same size.

BIBLIOGRAPHIES.

Both the starting point and the goal of research is information, and before any problem can be properly undertaken the research worker must determine from the literature that which has been done in similar fields or those closely related to it. Bibliographies, therefore, become a most important source of information. They are something which are time consuming for preparation, always represent a large amount of effort, and are expensive to duplicate. The use for any particular bibliography, however, is ordinarily limited to the few people working in that special corner, and consequently the publication of exhaustive bibliographies is seldom undertaken on a commercial basis. They are expensive to publish and very rarely have a circulation which justifies a publisher in undertaking their reproduction.

An interesting example of this is a certain work in zoölogy and other special fields in biology which has been published in Europe for some years. It is of immense assistance to research workers, and yet it operates with an annual deficit.

Some of our libraries issue carefully prepared bibliographies and notable among these are the libraries of the engineering societies and the Carnegie Library at Pittsburgh. The obvious importance of bibliographies and the infrequency with which they are published leads us to comment upon three which have recently appeared. Two of these "Chemical Warfare" and "Industrial Research" first appeared in *Special Libraries*, while the third, "The Production of Alcohol from Sulphite Waste Liquors," appeared in *Paper*. These have since been reprinted by Arthur D. Little, Inc., whose information department was responsible for the compilation. The ones upon Industrial Research and Chemical Warfare may be recommended to those interested in supplementary reading. A considerable variety of subjects is covered under the head of Industrial Research.

SCIENCE IN THE LEATHER INDUSTRY.

In the February number of the *Journal of the American Leather Chemists' Association* there occurs the following abstract from an article in *Le Cuir* entitled "Science Applied to the Leather Industry":

"During the war the overwhelming demand for leather forced the question of quality to be subordinated to that of increased production. Such a policy continued in peace times would spell disaster to the industry. A new struggle for commercial supremacy has begun that will require the production of leather of high quality at a low price. Regret is expressed that the commissariat did not know enough to profit by its unique opportunity to prepare for the after-war period, although this is to be expected where chemists and specialists are not represented. But it is the future, not the past, that matters now and the secret of solving present problems lies in the application of science to the industry.

"Methods of preserving hides should be investigated by means of our knowledge of antiseptics, bacteriology and the principles of putrefaction. Both physics and chemistry can be brought into play in determining the best methods of soaking to prevent loss of hide substance, and to deal most effectively with very hard and dry hides. Microbiology and chemical studies should be made of the liming process and of the actions of sodium and arsenic sulphides, both alone and mixed with lime. Much credit is due to Wood for his noteworthy bacteriological studies of bating, and to Proctor and Meunier for their works on the theory of tanning. A vast field for scientific investigation is offered in the matter of tanning materials which are now derived from all three kingdoms of nature.

"Although the above survey is brief, it indicates how much the development of the industry is dependent upon the application of science and the author hopes it may inspire tanners to wish to know more about such matters."

TEXTILE LEGISLATION.

Considerable editorial comment has been brought forth by the Barclay Bill (H. R. 2855), which has recently been brought before Congress. Briefly stated, the bill provides that no article of commerce may be marked in any way so as to give fraudulent, misleading, or inaccurate information as to weight, measure, numerical count, materials from which it is made, place where it is made, mode of manufacture, whose manufacture the product is, or information that its quality is superior to that which it really is, or information which is false, misleading, or deceptive in any other particular.

The bill intends to enable wholesaler and retailer to depend upon the guarantees of the producer, upon whom the responsibility for conforming to the law may be placed.

On numerous occasions effort has been made to give the ultimate consumer the same assurance that he is receiving that which he thinks he is buying in other articles beside foods, and certainly there is nothing to be said against the idea that the consumer should be properly protected against fraud of

any kind. However desirable such legislation may be, the difficulties to be overcome in enforcing the law are sure to be great and to involve rather extensive machinery. Due to the ideas which have been implanted in the minds of most of us with respect to the superiority of one type of material, say wool for example, it would be also possible for some particular section to profit largely. The writer believes in making it possible for the purchaser to know what he is buying, but he also believes in having the purchaser realize that nearly all fibers have their important place in our economic structure and that a piece of material may be better because of the admixture of the cotton with the wool. This does not relieve the manufacturer, wholesaler, or retailer from the obligation to sell such fabric for exactly what it is.

In some of our cities there are ordinances designed to deal with unfair competition and misrepresentation in advertising. In one of these cities the law has been enforced on occasion and the chemical laboratory has been successful in establishing the facts relative to the misrepresentation of merchandise, in this instance, silk. In Germany there have been a number of laws on this subject, the last of which is quite broad. The German bill goes so far as to give in detail advertising practices which are forbidden. Thus bankruptcy sales are very carefully covered and the merchandiser may not describe his sale as "On account of alterations," "direct from factory," "selling at factory price," "damaged by water," or "fire sale," unless the description fits the facts. Imagine some of our merchants being forbidden to use "hand-made," "selling at factory prices," "direct from manufacturer to consumer," and similar catch phrases unless such were the facts!

Great Britain also has an Act which covers much the same ground as does the Barclay Bill. The better class of merchants would no doubt welcome such legslation if it can be enforced in a way not to put a premium upon dishonesty. Some of our merchants have already established their own chemical laboratories, used as a protection both for themselves and for their customers, and the day is pretty sure to come when they will reap the benefit of their foresight.

PROTECTION AGAINST CARBON MONOXIDE.

Carbon monoxide is the poisonous constituent of illuminating gas and is responsible for the deaths of persons who prefer to commit suicide by the gas route. This same gas also causes trouble when burners upon gas stoves are not properly adjusted, or where the distance between the burner and the vessel to be heated is not such as to allow proper combustion. Carbon monoxide is also to be found in the exhaust vapors or fumes from internal combustion engines and is accountable for the death of several people who endeavored to work in a closed place with a running motor. Another source of danger from carbon monoxide is to be found in burning buildings which a fireman must enter. In coal mines and elsewhere, where explosives are used in confined places, carbon monoxide is a serious menace, and even in the metal industries fatalaties have occurred where illuminating gas is used for brazing, etc.

In addition to these various sources of danger in peace occupations there are so many military considerations that special work has been done to provide defense against it. At one time the statement was made that the nation which first learned how to use carbon monoxide in warfare would be sure to win, and while the gas could not be made available for warfare it does occur in considerable quantity where there is much gun-fire. Machine gun-fire, particularly in closed places, liberates large quantities. It is stated that in one of the naval engagements, defective high explosive shells evolved large quantities of carbon monoxide after penetrating into enclosed portions of ships causing the death of many men.

A new compound, which is called ohpcalite, was developed to remove carbon monoxide from the air. As first made it consisted of a mixture of 50 per cent manganese dioxide, 30 per cent copper oxide, 15 per cent cobalt dioxide and 5 per cent of silver oxide. Some modifications have since been made. The mixture gradually decreases in efficiency due to the absorption of moisture. This can be checked by weighing the container from time to time.

FIXED NITROGEN.

Professor Alfred H. White of the University of Michigan is the author of an article on "The demand and supply of fixed inorganic nitrogen of the United States," appearing in *Chemical and Metallurgical Engineering* for February 25th. An analysis of statistics is given and it is shown that in 1913, out of 626,000 long tons of Chilean nitrate imported 37.2 per cent was used for explosives, 45.5 per cent found its way into fertilizers, and 50.3 per cent served as raw material for the manufacture of chemicals. In addition 65,775 short tons of ammonium sulphate were imported, 15,000 tons of cyanamide were produced, and the domestic production of ammonia from coke ovens and gas works, calculated as ammonium sulphate, was equivalent to 195,000 short tons.

By going back to 1900, and plotting the curves for demand, sources and supplies it will be seen that an ever increasing amount of fixed nitrogen must be provided for agricultural and our chemical industries, including explosives. The question then becomes whether we can afford to allow the Government-owned plants for the fixation of atmospheric nitrogen to remain idle.

Professor White estimates that, based upon the capacity of the Government plants and the calculated demand, we must import 60.4 per cent of our inorganic nitrogen if the Government plants remain idle in 1920; but only 42.1 per cent if they are operated. This becomes 66 per cent and 50.5 per cent, respectively, for 1925, and 71.6 per cent and 60.7 per cent in 1930.

The two principal methods for the fixation of atmospheric nitrogen are by the synthetic, or Haber process, and cyanamide. Neither of these processes has so far proven a commercial success, and yet they represent the best that has been done. The Government plants exemplify these two principal processes. It is believed that the cyanamide plant in particular can be operated to produce fertilizer at a cost which will pay running expenses. In any event the United States cannot afford to be behind the procession in the study of nitrogen fixation. It is urged that steps be taken to bring the Government plants into production in order to diminish our dependence on imported material. The rapid increase in the installation of by-product coke ovens is an important factor, but even if all the coke produced in the country was made in by-product ovens the ammonium sulphate recovered would fall far short of meeting the demand for fixed nitrogen. Our war experience with nitrogen should teach a sufficient lesson to encourage further work on this subject.

HAIR DYE.

E. C. Gray is the author of a discussion on "The Dyeing of Human Hair," appearing in the *Color Trade Journal* of February. It seems that in the Western Hemisphere powdering the hair was the established custom for many years, originating in Rome, where gold dust was reported to have been used at one time. As late as 1806 the fashionable young men in London made a practice of powdering their hair blue, and an author of 1770 referring to the use of flour or meal for the purpose wrote, "Their hoarded grain contractors spare, and starve the poor to beautify the hair."

Any discussion of actual methods for hair dyeing is not to be found in the ancient records, probably because this was a trade secret of the beauty parlors. There has been a tremendous amount of fraud in connection with hair dyeing, as with all cosmetics and toilet articles. At times positively harmful materials have been employed, such as compounds of lead; lime, which acts destructively on the horny substance of the hair; and methyl or wood alcohol, which is poisonous and rather easily absorbed. The most effective hair dyes are those which form a precipitate practically coating or plating

the hair. Of course if an insufficient quantity remains upon the hair weird effects are seen, such as purple or metallic blue black gloss. Silver nitrate is sometimes employed and by drying in direct sunlight the black oxide of silver is produced. Potasium permanganate oxidizes to a brown color, the intensity depending upon the strength of the solution; and one homely formula consists in applying a water solution of the outer husks of the black walnut, which the small boy learned years ago will produce a decidedly black coloration of the hands.

In the East where eyebrows and eyelashes are often dyed India ink in gum Arabic and rose water is used. The coloring matter consists of finely divided carbon and so the dye is perfectly harmless. Another oriental formula depends upon changing the tannin bodies in nut galls into gallic and pyrogallic acids.

Three thousand years ago the Egyptians used henna and many other color-producing herbs for tinting their hair, eyebrows, and skin. In Persia, henna and indigo were used to produce a deep black color. Today the modern method, the henna pack, consists of applying the dye in the form of a paste which remains in contact with the hair from ten to thirty minutes. When it is considered that both the color and the texture of the hair are factors in this treatment, as well as the temperature of the air, it will be understood why hair-dyeing is really something of an art. If peroxide bleaching is used first, an expert hair dyer can produce almost any shade, partly by the skillful use of henna.

To be sure, the oil must be removed from the hair before any treatment, and further applications of dyeing material must be made according to the rapidity of the growth of new hair.

All things considered, it is evident that hair is far better left in its natural color.

PLATE ROLLING MILL.

C. L. Huston is the author of an interesting article in *Mining and Metallurgy* for January, describing the world's largest plate rolling mill.

Within the memory of Mr. Huston, the size of iron plates has advanced from a width of 26 inches, or even less, to 186½ inches in width. The old 26-inch plates were built up into boilers for the Mississippi River steamboats, while now the heads for great marine boilers can be made from a single piece. The article is illustrated by photographs of unusual apparatus and products including a large flanged head 183 inches outside diameter, 1½ inches thick, and containing three 49½-inch inside diameter flue holes. In addition to unusual mechanical equipment for which American mills are noted, accomplishments of this sort require a deal of science to make them possible. There are questions of heat control, of raw materials in the rolls and other parts of the unusual apparatus, and the composition of the ingots upon which the work is done.

When one considers the excellence of the mechanical appliances that have made the rolling of these great plates possible, it is but natural to hope the day may soon come when the scientific work applied to the steel industry may be said to have reached the same degree of perfection.

TRADING WASTES.

In discussing the chemical progress of Germany, reference is often made to the formation of certain combinations which have made it possible for one plant to work upon the waste products of another, by which arrangement both plants were placed in a more advantageous position. Due to our anti-trust laws, it has been necessary for our corporations to be very careful concerning their relations and it is only occasionally that we find a chemical manufacturer so placed that he can invest in a second establishment so planned as to exchange its wastes for those of the older establishment.

One company which now manufacturers sodium carbonate proposes to engage in the fixation of atmospheric nitrogen and to use in its soda plant the surplus carbon dioxide of the nitrogen plant, the soda plant at the same time supplying to the nitrogen plant calcium chloride, which is a residue from the manufacture of soda.

The excess carbon dioxide is obtained as a by-product from the production and purification of hydrogen. These are produced in large quantities in the synthetic ammonia process. About 11 tons of carbon dioxide is obtained for every ton of pure hydrogen.

Carbon dioxide is much needed in the manufacture of soda and this is usually obtained from lime kilns, where limestone is burned with coal. By passing the carbon dioxide through heavy salt solutions the carbon unites with the sodium and forms bicarbonate.

A by-product of this process is calcium chloride, which thus far has been pretty much of a drug on the market. Under the new arrangement this sludge of calcium chloride will not be produced, but instead plants engaged in nitrogen and ammonia operations will get ammonia in a form suitable for direct application to the soil as a fertilizer. Indeed, ammonium chloride is considered as valuable as ammonium sulphate for this use.

The arrangement described should do much to reduce production costs, for there will be many tons of sulphuric acid saved, as well as great quantities of lime and coke or coal.

DRYING COAL PRIOR TO COKING.

When the problem of producing coke with a low ash content from a high ash coal was solved, the problem of economically drying the coal remained. It was comparatively simple to apply the principle of the ore concentration table and recover cleaned coal from the tailing discharge. The coal washed in this manner comes from the conveyors with about 16 per cent of moisture and even a drying of three days' duration does not reduce this moisture more than 6 per cent. Sometimes the net result is a reduction of moisture to 8 per cent.

It is an interesting fact that water has been observed to flow out of the base of a bee-hive or by-product oven into which washed coal has been charged, and in the lower layers of such a charge a water content as high as 50 per cent has been observed. The water present has a highly destructive action on the walls of the retort and results in even greater losses in gas, oil, tar, and ammonia. Longer cooking hours are necessary, one-third of the tar and oil is destroyed, and it is estimated that 20 per cent of the ammonia is also lost.

It is seen, therefore, that drying the coal is highly important and experiments are now under way with a centrifugal dryer capable of treating 75 tons of coal per hour. This apparatus reduces the moisture to from 6 to 8 per cent, which is hardly enough of a reduction to excite enthusiasm. It is suggested that if the coal could be heated a better separation could be obtained. The question now seems to be whether it would be better to charge dry, warm coal into the coke retorts, and if by pre-heating the coal previous to charging it may be possible to make coke in 12 hours.

SODIUM VS. POTASSIUM.

This controversy grows out of the original availability of the two alkalis, potassium salts at one time having been more easily obtainable than sodium, caustic and carbonate. Later Germany was given a natural monopoly of potassium salts through the discovery of the Strassbourg deposits, and still later comparatively cheap electrolytic methods were devised for producing sodium hydroxide, soda ash likewise becoming plentiful.

The result has been that many of our textbooks continue to specify potasium as the only alkali with which many reactions can be carried on efficiently, and their methods require its use in much of the laboratory work. It was years before it was found that sodium cyanide was just as satisfactory for metallurgical operations as potassium cyanide, and of late much work has been done to show that most of the reaction essential to qualitative and quantitative analysis where alkalis

must be used can be carried out with equal satisfaction by employing sodium.

An instance worthy of emphasis is that of synthetic phenol, where according to the textbooks, in which statements of previous authorities are often taken at their face value without experiments to check their accuracy, potassium hydroxide must be used if satisfactory yields are to be obtained. This statement has been widely copied throughout the literature and is probably based on insufficient and faulty experimentation or carefully planned potash propaganda. In this country we were compelled to produce phenol during the war without potash and one of the companies assigned the problem to their research laboratory with the result that ways were found of obtaining just as good yields in fusing sodium benzene sulphonate with sodium caustic to produce phenol as could be obtained with potassium hydroxide. In large scale production ninety per cent of the theoretical yield was obtained, which is believed to be as high as yields attributed to potash. By very careful control yields of ninety-four per cent of that theoretically possible were obtained in experimental fusions, and two investigators found that by excluding air they could actually obtain ninety-nine per cent of the theoretical yield when using sodium benzene sulphonate and sodium hydrate. This process yields sodium sulphite as a by-product, which salt is employed in the purification of tri-nitro-toluol.

ORGANIC RESEARCH.

THE medical profession is greatly interested in anything that will increase the amount of fundamental organic research in the United States, and this requires improvement in the facilities for the manufacture of dyestuffs and other organic chemicals. We have really just begun to get results in that interesting field where chemistry and medicine meet and there is every reason to believe that further experimentation will lead to the discovery and utilization of new substances that will be of the greatest efficiency in the treatment of diseases. Chemotherapy needs an almost unlimited number of chemical compounds. For example, 605 organic compounds were tried out before Salvarsan, "606," was found. This compound can no doubt be improved upon, but it requires the development of new compounds for the purpose. Veronal, a drug much used to produce sleep, procaine (nevocaine), which is the monohydrochloride of paraamidobenzoyldiethylamidoethanol; are the results of organic research. Luminal is said to be better than veronal, but it is not yet obtainable in this country. Quinine may be made synthetically while chloramine T and similar new compounds have become of great value in treating infected wounds. In practically all instances where American chemists have undertaken the preparation of these complex compounds they have produced highly satisfactory material at lower cost than had been paid before the war. Indeed it had become the custom abroad to make a few specialties pay for all of the other compounds produced as by-products in the synthesis and therefore to carry the burden for the whole series of compounds, leaving the others to yield the net profits. We surely cannot afford to be without every facility for research work of this character.

CHINESE DYES.

SO MUCH has been written and said concerning synthetic dyes that many have forgotten the fact that a large number of important colors are still derived from the vegetable kingdom. The following statements with reference to the native dye industry in China are taken from the *Color Trade Journal*, Vol. VI, No. 2, February, 1920:

Just before the outbreak of the war German synthetic indigo was imported into China to the extent of 10,000,000 taels a year, in addition to a large quantity of German aniline dyes. These had replaced in great measure the native vegetable dyes in which China was so rich; in fact, indigo was no longer regarded as one of China's agricultural products. The native dye industry, however, by force of circumstances, has been revived, and dyes are now appearing in the list of exports.

Of first importance is indigo. It is grown quite generally throughout China for local purposes, but assumes greater importance in trade in the south. It appears that one acre of ground will produce about 6,000 pounds of indigo. According to tests made by the United States Bureau of Foreign and Domestic Commerce, the Chinese indigo contains only about 1 per cent of pure indigo. Thus an acre will produce, with a good crop, about 60 pounds of pure indigo. The plants are cut before flowering, steeped in cold water for some days, and well stirred. After the plants are removed the water is again stirred, and slaked lime added to precipitate the dye. In 1917 China exported 78,148 piculs (picul equals 133 1/3 pounds) of liquid indigo, valued at $700,000. In 1918 the figures were 83,642 piculs, valued at $900,000. Kiukiang and Swatow are the principal ports of export.

Yellow is produced from the flower buds of the locust tree (*Sophora japonica*), which are baked to a light brown color, placed in cold water, and brought to the boil. Alum is used as a mordant. The powdered roots of *Curcuma longa*, or tumeric, are also used for a yellow dye, especially for cotton fabrics.

Red is produced from safflower, grown in Szechwan. Balsam (*Impatiens balsamina*), *Anchuse tinctoria*, and *Lawsonia alba* are also used, the latter to produce the rouge used by women. The *Rubic cordifolia*, a creeper, is used to make a deep red.

Green dyes for cotton cloth are produced from the bark of the *Rhamnus parvifolius*, found in Szechwan. Green dye is also made from the leaves of the *Rhamnus tinctorius* and other species of the buckthorn.

Brown dye is produced from the false gambier, grown extensively in southwestern China. The darker browns are produced by the addition of gall-nuts and alum. A brown cloth that is very popular in the summer with the Chinese is a dyed grass-cloth with a bright lustre and a waterproof appearance. Its distinctive qualities are the result of the dyes made from the false gambier.

The vegetable dyes of China are particularly well suited to Chinese rugs. These dyes will outlast the rugs. Exclusive of indigo, China exported nearly 2,000 tons of dyestuffs during 1917.

ASBESTOS PAPER.

IN *Chemical and Metallurgical Engineering*, issue of February 4, 1920, is an abstract on the history of asbestos paper based on investigations at the Bureau of Mines. It seems that asbestos was used by the ancients for winding sheets, table cloths, and similar fabrics. It was a woven and not a felted product, and therefore, is not to be confused with asbestos paper. One of the earliest references to asbestos paper was published in 1750, and it would seem that the primary object at that time was to obtain an indestructible writing paper, although the report states that while the paper did not burn, the writing disappeared. One hundred years later further efforts were made with the same object. In 1853 a patent was issued for a process for making asbestos paper and many experiments have been made to produce suitable asbestos printing paper. Asbestos paper, however, is not well adapted for printing and writing because it does not have a smooth surface and in absorbing ink, behaves more like blotting paper. Therefore some of the papers have contained but small quantities of asbestos, the remaining fibres being combustible, but upon burning a white residue, which maintained its shape and preserved the written characters, would be found.

Asbestos paper has also been used for ornamental wall paper and carpet linings and during the last twenty-five years new uses have dominated its production. At present some plants manufacture as much paper in a single day as was produced annually twenty-five years ago. In addition to paper, mill boards of various thicknesses have also been produced and the chief uses of these products are insulation, roofing, building, paper lining for stoves, air cell pipe covering, high pressure gaskets, and packing.

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

ELECTRIC HEATING AND COOKING.

The scarcity and high cost of fuel are giving a great impetus to the movement of the electrical industry for the complete "electrification" of the home and the factory. Of timely interest is, therefore, the report made by Dr. K. Norden to the Society of German Electrical Engineers, which report was read at their annual meeting on September 27, 1919 (*Electrotechnische Zeitschrift*, October 16, 1919, Vol. 40, page 518-20). Dr. Norden discusses the status of the electric heating of the home and of the industrial plant, of electric cooking and of electric heating in various industrial processes, his conclusions being based on conditions in Germany.

The heating of the home by electricity on a general scale does not seem to be possible of realization in the nearest future. It would necessitate first a low rate for power; for instance, in order to compete even with the present high prices of fuel in Berlin, the electric power would have to be sold at 4.5 pf. per k.w.h. Again since electricity is first applied in those fields where its present cost is justifiable, namely, for lighting and motor energy, it is evident that only that amount of energy which is left over in the central station would be available for home heating. Granting that both—a low rate for power and a great reserve of energy are available—there still remains the question of the additional distribution circuits and line apparatus.

On the other hand, the heating of industrial plants by electricity can be introduced in the nearest future, for the relative amount of energy required is much less and, furthermore, almost each and every plant is either connected to a high pressure feeding line or has a power-plant of its own. However, in order to be successful, the introduction of electricity as a source of heat will have to be based on the principle of heat accumulation or storage, which principle would allow the use of the electric current for heating purposes during the non-rush period or idle hours—like the lunch hour, etc. In this connection it must be stated that the electrical engineer must devote himself to the serious study of the principles and technique of the science of heating and ventilation if he is to introduce successfully electricity as a source of heat. Special courses should be given in the electrical engineering colleges while the older generation should avail itself of extension courses on this subject. The theory of heating presents also a very interesting subject for further industrial research.

The modern factory may be heated electrically direct by separate stoves scattered throughout the plant, or by central heating stations providing hot air, steam or hot water heat, which stations would use electric energy as a source of heat. If the direct method of heating is used the conventional stove having for its heating unit a resistance wire wound on a porcelain base will have to be discarded: its life is short and its surface temperature too high; therefore it is unhygienic and may cause fires. The heating element should be more accessible to the air, and the temperature at its surfaces should not exceed 100°. Again the electric stoves will have to be built on the principle of heat storage; the heat absorbing element may be either a liquid or certain minerals or use may be made for this purpose of the heat of melting or of the heat of chemical dissociation.

The central electric heating station is quite feasible, and reliable equipment has been offered by the German manufacturers. The boilers of such installations are to be built in such a manner as to allow of their operation either in the usual manner or on the principle of heat storage. For the present it is hardly advisable to discard entirely the coal burning equipment; the latter should be used entirely during the very cold period, should be supplemented by electric heating during the moderate weather, while only electric heating should be used for intermittent operation or during cold spells of short duration.

While Mr. Dettmar discussed the possibilities of electric cooking as far back as 1911 it has made but little progress in Germany. This must be met by a strong publicity campaign accompanied by opening of free schools for electric cooking; the technic of the electric kitchen has been improving, but much has to be accomplished as yet. The greatest obstacle, the high rate of consumption of energy, must be eliminated by the design of an electric heat box or a stove built on the principle of heat storage.

As to the electric heating of apparatus used as machines or tools in various industrial processes, its advantages have been known and quite well understood. The methods of control are accurate and reliable; only the needed amount of heat carefully measured is introduced and all utilized; the installation is less complicated, cheaper and takes less space than in the case of steam or gas; especially is this true for machinery in motion.

The immediate need is a thorough standardization of all apparatus used in connection with electric heating and cooking. In many cases numerous types of the same appliance exist which could be reduced to several most convenient sizes. The same holds true of various machinery electrically heated. In order to succeed the electrical engineer must seek the co-operation of the designers of such machinery.

ELECTRIC FURNACE DEVELOPMENT DURING 1919.

During the war a great impetus was given the electric furnace for steel manufacture. After the armistice had been signed there seemed to be some question as to whether the use of the electric furnace would be extended as rapidly as indicated during the period of war. However the electric furnace has been easily holding its own, many customers frequently specifying electric steel for more important work.

At the expiration of the year just passed approximately 850 electric furnaces for the production of steel were in use throughout the world, about 375 of which were located in the United States and Canada. Some 20 different concerns manufacturing or selling various makes of electric furnaces are at present in the American markets, this is an increase of perhaps 5 over the year previous. During the year approximately 45 electric steel-making furnaces were either placed in operation or contracted for in the United States and Canada.

The tendency has continued during the past 12 months to further increase the manufacture and sale of polyphase furnaces of arc type. The use of single phase or induction furnaces, especially in larger sizes, has been practically abandoned by steel makers. Opposition to the latter two types is due to their unfavorable operating efficiencies and to the unsatisfactory load conditions which they produce on power circuits. A number of minor changes have been recently made in the mechanical and electrical designs of electric furnaces. Less complicated mechanisms for tilting and better facilities for changing roofs, relining, charging, slagging, pouring and speeding up the furnaces have been adopted. Furnace electrodes are said to be of better quality than those formerly available, but little improvement has been noted in the refractories used for furnace linings.

The demand has been mostly for furnaces of capacities not greater than 15 tons; it seems that the small sizes are able to show marked economies, furthermore, many purchasers prefer to make their initial investment in smaller sizes so as to try them out before tearing away their fuel burning furnaces. In comparison with the crucible furnace, the converter and the small open hearth furnace many users concede the cost advantage to be in favor of the electric furnace. Some manufacturers of tool and special high-speed steels contend, however, that the product of the crucible cannot be equalled by the electric furnace. Whereas this contention may possibly be open to question, the fact that many other crucible plants are now using electric furnaces goes to show that this opposition is gradually disappearing.

Considerable discussion has taken place during the year regarding more extended, new and heretofore unthought of uses of the electric furnace. The application of the duplexing process whereby steel is preheated in the converter or open hearth furnace and later refined and superheated in the electric furnace, has been further developed. In fact several new installations of this sort have been made during the year. A number of experiments have been made in the use of the electric furnace in gray iron and malleable foundries. Where especially sound and fine cast or malleable irons have been needed for pouring light or thin section castings, this application of the electric furnace has exceeded expectations. It is well known that by ordinary means of production considerable phosphorus is required for making gray iron or malleable castings, in order to secure the proper degree of fluidity. As any desired superheat may be obtained in the electric furnace, iron much lower in phosphorus content may be used, and greater strength and toughness in the castings may be attained.

Much desirable datum is yet to be gained and collected on physical tests of electric steels. Some valuable information of this sort has been collected by the Electric Furnace Association. The association was formed during the past year. Its membership is open to makers of electric furnaces and their auxiliary equipment, as well as to those directly interested in the products of the electric furnace.—From *Blast Furnace and Steel Plant*, January, 1920.

AUTOMATIC SUB-STATIONS.

The rapid progress which is being made in the adoption of automatic sub-stations is indicated in a recent report of the Committee on Power Generation presented at the convention of the American Electric Railway Engineering Association at Atlantic City, N. J., and abstracted in *Power*. While the principle is not new, and installations were known where the rotary transformers were placed in unattended sub-stations, and with the batteries controlled from the generating station, yet it must be admitted that these were only semi-automatic. The present-day installations, on the other hand, are entirely automatic, going on load when the demand calls for it, and switching themselves out when the load falls off.

The first automatic sub-station control was put into operation as recently as Christmas, 1914. In 1917 the first installation involving the operation of two synchronous converters in series was made, and in 1918 two synchronous converters were first automatically operated in parallel. Four and one-half years after the first experiment was made there were 35 full-automatic and two semi-automatic, or remote controlled sub-stations in actual operation and in addition 31 automatic and four semi-automatic equipments stood on order with manufacturers. Rotary converters as large as 1,000 k.w are handled automatically, while a 2,000 k.w. motor-generator is about to be put into service, and a 3,000 k.w. synchronous condenser is running. It is clear that the system has proved successful.

The first automatically-controlled water wheel generating station, which contains three 500-k.w. generators arranged to operate in parallel either under the influence of full-automatic control at the generating plant or controlled if desired by an operator in the main steam-generating station at a distant point, was put in operation in 1918. The success of this installation makes possible the development of a considerable number of small water powers that otherwise could not be developed because of the cost of operating labor. By using asynchronous generators the difficulties of speed regulation and synchronizing can be overcome, and the control reduced to its simplest terms.

Several companies have chosen automatic equipment in consideration of saving in labor. The largest figures received gave an estimated saving of $400 per annum on a 300 k.w. station and $700 on a 500 k.w. station. One company installed a 250 k.w. automatic station to replace a floating battery between two sub-stations ten miles apart, in preference to spending $5,000 for necessary repairs to the battery. When some of the automatic sub-stations were built in new locations, however, it was in several cases possible to remove feeder copper which possessed a value sufficient to offset in part the cost of construction of the sub-station building with its equipment. In an exceptional case the cost of construction of a two-unit sub-station containing two 300 k.w. synchronous converters was more than offset by the value of the feeder copper that was removed from the distribution system, and a more satisfactory line voltage was maintained on the line as a whole. The most notable saving of copper was made in Des Moines where, through an installation of a system of automatic sub-stations, an amount of feeder copper was taken down which was worth $90,200, and at the same time a sub-station and distribution system were obtained which cost according to estimate $141,700 less than an equivalent system to give the same voltage regulation would have cost, had additional manually operated synchronous converters been placed in the central power station and additional feeder copper put up on the outside lines. The example is somewhat unusual but is given here to illustrate the possibilities that are offered in not a small number of cases.

It was brought out in the discussion on this report that at the present time the economic limit in automatic sub-station capacity is about 6,000 k.w.; above this limit it is more economical to install manually operated equipment.

USE OF ALTERNATING CURRENT FOR TELEGRAPHY.

The shortage of batteries and their high cost in Europe induced French and Swiss engineers to experiment with alternating current as delivered by the ordinary industrial circuits, as a possible source for the telegraph apparatus. The experimental section of the French postoffice has conducted elaborate tests at its Brest station. This installation has given such satisfactory service that it is proposed to apply alternating current in the main telegraph centers.

A complete and illustrated description of the above installation is given in *Annales des Postes, Télégraphes et Teléphones*, Vol. 8, September, 1919, p. 446-461, a good summary of which also appears in the *Technical Review* of London.

The alternating supply is taken from three-phase mains through a bank of transformers. On the secondary side the current is rectified by a mercury vapor rectifier with three cathodes. A buffer battery is connected between the neutral point of the secondary windings of the transformer and the cathode of the rectifier. Between the battery and the rectifier lies an automatic switch, which disconnects the rectifier leads if the current changes its direction owing to a drop of voltage across the rectifier terminals, and reconnects the rectifier to the battery when the voltage rises again. During the period of disconnection the Morse, Hughes and Baudot telegraphic apparatus is supplied by the buffer battery alone. A red lamp signals this state of affairs, and if the attendant ascertains that it will last for a prolonged period he prepares a reserve battery of cells for use. This reserve battery is always availa-

ble for use but the cells are kept dry until an emergency arises.

In order that the arc of the mercury vapor rectifier may not become extinguished when the call for direct current falls below the minimum value that will maintain the arc, a permanent shunt taking from 1.5 to 2 amperes is connected between the cathode and the neutral point of the transformers. Normally the battery voltage is slightly lower than the rectifier voltage, so that the battery does not discharge, but is slowly charged.

If a motor generator set were used to replace the local batteries of the Baudot sets, it could be driven by a direct-current motor connected to the buffer battery. This would simplify the above-mentioned arrangement by rendering the permanent shunt unnecessary, and this would render current reversal impossible and permit the automatic switch to be dispensed with.

ELECTRIC LOCOMOTIVES FOR INDUSTRIAL PURPOSES.

The electric locomotive has attained a well established place in our everyday commercial and industrial life. The rapid and efficient transportation of material in all lines of industry is becoming more important every year.

There are three general forms or types of locomotives, viz.: straight trolley, straight storage battery and the combination of both storage battery and the trolley. Each type has special merit and points of advantage according to the conditions under which it is required to operate.

The trolley type is the original and thoroughly proved type and is more common one in use for all purposes, particularly in mining service, but owing to the disadvantage of having trolley wire or collector rails around industrial plants, it has never been adopted to the extent that would be expected in view of the demand for electric locomotives for such service. Wherever the conditions permit using the type with safety, and particularly where the haul is long and loads heavy, it is the logical one to use. In many cases special forms of collector rails and other devices can be used which largely remove the danger to workmen, but where safety considerations are paramount and where fire risk is an important factor the storage battery type is better adapted. The motor capacity is much greater than for storage battery types; at operating speed the draw-bar pull is based on an adhesion factor of 20 per cent of locomotive weight with chilled cast iron wheels on clean dry rail. With steel-tired wheels this is increased to 25 per cent. For starting, an adhesion factor of 33 1/3 per cent with the use of sand on the rail is permissible. The motor equipment in all cases produces tractive effort sufficient to slip the driving wheels, thus providing protection against injurious overloads. For all conditions except heavy high-speed freight service the two-motor equipment with single reduction gearing is used, having a speed of 6 to 8 miles per hour under full load.

A modification of the trolley type designed to handle freight cars at the ore docks is called the "pusher" type. The car tracks run directly under the ore shutes, and the locomotive track is placed between the regular tracks. The push poles operated by air extend out on each side and can be raised to a vertical position when not in use. To move cars the pole is dropped between the end sills of two coupled cars of a train, pushing cars or retarding same as desired; it is equipped with steel cable and hook attached to front end for pulling cars out of reach of push pole. One of the chief advantages of this method of handling cars is the fact that the locomotive can control cars on two tracks at one time, spotting cars on one track, while the cars are being loaded on the other. In addition to this the motorman is in position to see when cars must be moved, or to receive signals direct from the main operating ore dump.

The main characteristic of the storage battery locomotive is the storage battery itself. Fortunately, it is today produced in a form which withstands the most severe mechanical strains caused by the rough operating conditions usually encountered, and from an electrical standpoint operates efficiently both in regard to cost of power and maintenance. The design of the motor and of the auxiliary electrical equipment have been brought to an equally efficient plane. This has resulted in the production of high-speed motors driving through double reduction gearing, designed for running on the minimum voltage considered practical, and having a low current rating which makes it possible for the daily cycle of operation in many cases to be performed with one charge of a battery such as can be applied to a locomotive of reasonable dimensions. In addition to this methods of control are used which enable the motors to be accelerated with a minimum amount of current wasted through the resistance. The mechanical design has kept pace with the electrical equipment now available, resulting in light weight but thoroughly reliable locomotives.

The next important consideration is the selection of the storage battery, with special reference to the cycle of operation required for the period of the average working day as well as the weight of the loads to be hauled. Owing to the fact that the battery has a limited amount of energy, the work it will perform depends in large measure upon the rate at which it is called upon to deliver this energy. The speed of storage battery locomotives is necessarily slow and the character of work performed is not such as to require high speed.

It is quite difficult to standardize storage battery locomotives. The three sizes given below have been found to satisfy most of the industrial or mining requirements:

Nominal Wght. of Chassis, lbs.	Nominal Drawbar Pull, lbs.	Nominal Speed, m.h.p.	—Motors— Voltage	Total h.p.
6,000	1,000	3.5	30	11
8,000	2,000	3.5	80	23
10,000	3,000	3.5	80	32

Storage battery locomotives of larger type have been built but without any attempt at standardizing to the same extent. The tendencies are towards large batteries and increased motor capacity, and towards a slower speed motor suitable for operating with an efficient single reduction gearing.

The combination trolley and storage type can be used only where conditions warrant. The added flexibility to be gained by the storage battery is important in covering a large area with a minimum expenditure for overhead construction as well as offering a solution for combined indoor work where trolley wire would be prohibited with outdoor work where loads and length of haul might be beyond the capacity of a reasonable sized battery, without frequent recharging or changing of batteries. The battery is charged while locomotive is operating on the trolley thus saving time.

The chief disadvantage is the difficulty of applying a battery of necessary capacity without exceeding the permissible weight for the motor equipment, however, where the period for battery operation is short compared with that for trolley operation the battery capacity can safely be much smaller than would be the case for straight battery operation.

Comparing the electric locomotive with his nearest and commonest competitor—the steam locomotive—it is found that the former is more desirable. While the initial cost of the two types is about the same the maintenance and operating costs are greatly lowered and of a definite value in the case of the electric locomotive. It requires a minimum of repairs, the fuel is used very economically and the fireman is eliminated. It is figured by many industrial plants that the electric locomotive pays for itself in from three to four years.—Walter Fixter and Kenneth Andrew. Association of Iron and Steel Electrical Engineers, November, 1919, pp. 9-34. *Journal of the Engineers' Club of Philadelphia*, January, 1920.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

BLAST ENGINE WITH REACTION JET PROPULSION.

At the recent Paris aeronautical show there was exhibited a trial machine embodying the Mélot principle of propulsion. It is stated that the inventor experimented during the war at the Laboratoire du Conservatoire des Arts et Métiers in coöperation with the French Ministry in Munitions.

The machine consists of a burner with fireproof lining. Into this an explosive mixture is injected and ignited in the first instance by a spark plug, after which combustion continues uninterruptedly. The burned gases are exhausted through a blast pipe and four blast "engines," which are really graduated nozzles, one large and three small.

At the inlet mouth of each of these nozzles air is drawn in by suction, and the whole mixture of air and burned gases is

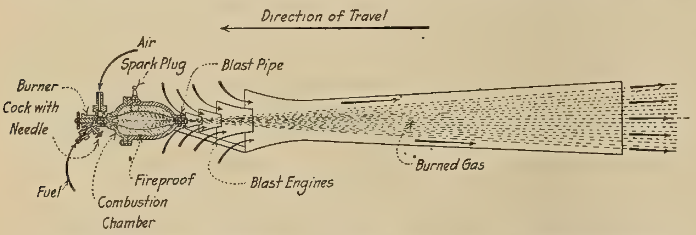


FIG. 1. MELOT SYSTEM OF PROPULSION FOR AERONAUTICS

exhausted by the last and largest blast engine and makes a direct thrust against the air at the rear of the engine (Fig. 1).

The machine is said to give 30 h.p. for a relative speed of 50 m. (164 ft.) per sec. The weight per horse-power is said to be 0.5 kg. (1.1 lb.), and it is obvious that if the machine is capable of functioning for any length of time, its cost ought to be quite low because of the absence of valves, pistons and other parts of the conventional engine.—*Aeronautics*, Vol. 18, No. 331 (New Series), Feb. 19. 1920, p. 157, 2 figs.

DOES PICKLING AFFECT THE QUALITY AND MACHINABILITY OF STEEL?

By H. L. Hess, Mem. Am. Soc. M. E.

Pickling is extensively used, as it facilitates the discovery of seams and surface defects generally, and removes all furnace and rolling scale. Various solutions are used, such as highly diluted baths of sulphuric or hydrochloric acids.

A series of tests were carried out by the metallurgical department of the Hess Steel Corporation, Baltimore, Md. In these tests 1 lb. of a special pickling compound (not otherwise specified) was dissolved in 3 gal. of water, and the mixture held at a constant temperature of about 200 deg. fahr. The tests were made on round pieces (1½ in. in diameter and 3 in. long) of chrome steel with approximately one per cent carbon and 1.50 per cent chromium.

As the object was to determine the lasting effect of the pickling on the metal, various subsequent treatments were used in order to neutralize fully or partly the effect of the pickling, the pieces being washed in cold, hot or lime water and tested either immediately or after periods varying from 7 to 28 days. The tests were made for hardness without cleaning, polishing or filing the surfaces in any way previous to the test, this being done in order to avoid the possible removal of a skin which might have appeared as a result of the pickling.

On the whole it was found that the hardness results do not seem to be affected by the pickling treatment, although there was a slight indication that the unpickled steel has a somewhat softer surface than the pickled specimens.

Careful machining tests showed absolutely no difference in machinability, and it would appear that pickling affects only the skin, and even that to an effect not noticeable in machining.

Further tests were made to find out, if possible, whether pickling would have any effect upon the surface of the material and whether this effect were traceable to any appreciable depth. In these tests each piece of steel was subjected to a careful microscopic examination of the surface before and after aging and at various magnifications. The photomicrographs do not show any distinct difference between the pickled and unpickled bars.

The general conclusion drawn from these tests is that pickling in itself, as well as pickling followed by various treatments, does not interfere in any noticeable way with the quality or machinability of the steel.—*Iron Age*, Vol. 105, No. 9, Feb. 26, 1920, pp. 593-594, 6 Figs.

PRESENT STATUS OF THE CONCRETE SHIP.

The original program of concrete-ship construction of the Emergency Fleet Corporation was reduced after the armistice to a total of fourteen vessels, and in October, 1919, contracts for two 7,500-ton cargo-vessels were cancelled.

At the present date there are in service three 3,500-ton cargo vessels and one 3,000-ton cargo vessel, three 7,500-ton tankers and twenty-one 500-ton canal barges built by the Railroad Administration under the supervision of the Emergency Fleet Corporation. The remaining vessels are in various stages of completion and are expected to be in commission by next summer.

In general, it is stated that in carrying out this program no construction problems were encountered which were not successfully met. The experience of the vessels in service thus far indicates that for cargo vessels there is ample structural strength, and that the barge is a much simpler problem in concrete than in usual materials.

On the other hand, it was not found that reinforced-concrete hulls could be built with greater speed than steel hulls, the average time of constructing the concrete hull being seven months.

In service concrete ships stood up quite well. In fact, there is generally less vibration in concrete ships than in corresponding steel ships, and also a considerable increase in the period of roll, which is desirable, and is apparently due to the fact that these vessels have a larger moment of inertia around the longitudinal axis than steel ships, because the mass of the concrete shell is considerably greater than the mass of the shell in a steel ship.

On the other hand, experience seems to indicate that these vessels are unable to withstand severe concentrated blows on the shell without the shattering of the concrete.

Impact, which in the case of a steel ship would probably only cause indentation of the plates, in the case of the concrete ship is apt to cause a shattering of the concrete over the area adjacent to the point of impact.

Repairs, especially in the case of barges, are, however, relatively simple and can be effected with little loss of time and at small cost.

The dead-weight capacity of the concrete ship was found to be lower than expected, the actual ratio of dead-weight displacement being on the average little more than 0.50. Furthermore, in the case of a steel ship and a concrete ship having the same dead-weight capacities, the concrete ship

because of the greater weight of the ship itself must have greater dimensions than the steel ship, and in consequence must have greater hold spaces. For heavy-weight cargoes such as steel, coal or oil, in which the dead-weight capacity is reached before the hold spaces are filled, steel has obviously an advantage over concrete as a material of construction, assuming that construction and operating costs are equal. For bulky cargoes, such as ordinary goods, cotton, fruit or other materials for which the space required exceeds about 70 cu. ft. to the ton, the concrete ship will actually carry more dead weight than the steel ship for the reason that the hold spaces of the steel ship will be filled before dead-weight capacity is reached.

The report expresses the opinion that no definite conclusions should be drawn as yet from the experience of these vessels; and that the only general conclusion therefrom seems to be that it is possible to construct ships of concrete in about the same time, and for approximately the same cost as corresponding steel ships, which would indicate that with more experience in the art it will be possible to reduce both the cost and the time for construction. As regards the length of life of concrete ships, no sufficient data are available, and the brief experience of vessels afloat has disclosed no serious inherent weakness to shorten the life of a concrete ship.—Report read at the Convention of the American Concrete Institute, at Chicago, Feb. 16-18, 1920, by Committee on Reinforced Concrete Barges and Ships, H. C. Turner, Chairman. Abstracted through *Engineering News-Record*, Vol. 84, No. 10, March 4, 1920, pp. 463-464.

INVESTIGATION OF MUFFLING PROBLEM FOR AEROPLANE ENGINES.

By G. B. Upton and V. R. Gage, Members Am. Soc. M. E.

Data of tests carried out under the auspices of the National Advisory Committee for Aeronautics on a Curtiss aeroplane engine and several stationary and other engines using a fan dynamometer.

The paper describes in considerable detail the methods of measurements and the formula used. As regards the relation

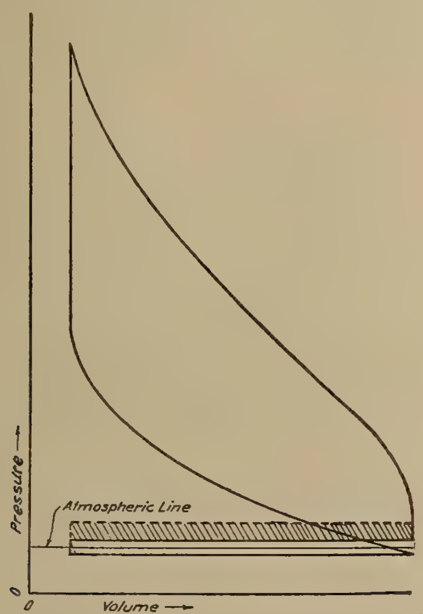


FIG. 2. INDICATOR DIAGRAM SHOWING LOSS OF POWER THROUGH BACK PRESSURE AT EXHAUST VALVE

between back pressure and power output, it appears to have been found that for moderate back pressures, the power loss is substantially proportional to the back pressure, while for higher back pressures the power loss amounts rapidly, apparently at such a rate that a back pressure of even less than 10 lb. per sq. in. would stop the engine.

A possible explanation of this changing effect of back pressure as the back pressure increases may be found by considering the indicator card. This is schematically shown in Fig. 2. For small back pressures we may expect the main effect to be a lifting of the exhaust line of the card by an amount substantially equal to the increase of back pressure. The result would be a loss of indicated mean effective pres-

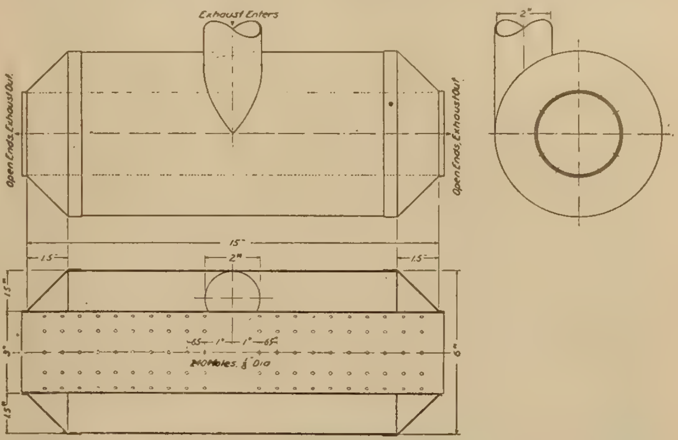


FIG. 3. TANGENTIAL-WHIRL-CHAMBER TANK MUFFLER RECOMMENDED BY THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS FOR THE LIBERTY AIRPLANE ENGINE

sure equal to the back pressure, because the elevation of the exhaust line would extend through the whole stroke. The loss of brake mean effective pressure will be smaller than the loss of indicated mean effective pressure in the ratio of the mechanical efficiency of the engine to unity.

At higher back pressures the exhaust gases are held back in greater amounts in the cylinder, leaving the clearance space, at the end of the exhaust period, filled with an abnormal weight of hot, dead gases. These re-expanding, interfere with the incoming charge in various ways, lessening the amount of the fuel mixture drawn in. The decrease of charge quantity will result in a decrease of the mean effective pressure which is added to the decrease of mean effective pressure due to lifting of the pressure of the exhaust line.

Probably it is the decrease of charge which is the principal reason for the possibility of stalling the engine by fairly completely choking the exhaust pipe and before complete closure is reached.

It was also found, as regards the relation between the brake horse-power and the actual back pressure, that "the back pressure increases as some exponential function of the horse-power, when the conditions of the exhaust passages remain unchanged." [Quoted literally.—Editor.]

Data are presented to demonstrate that the choking of the exhaust by sharp turns, pipe fittings, etc., gives the same results as choking by a muffler.

In the course of the experimental work carried out some peculiar phenomena were noted. One such was the abnormal power drop, considering the back pressure, at certain critical speeds. It was found that this abnormal power loss could be avoided by a very small change of speed either way from the critical.

The critical speed changed or disappeared with change of exhaust manifold. The supposed cause of this abnormal power loss at the critical speed is a reflected wave of exhaust gas killing the clearance of some cylinder just before its exhaust valve closed.

A number of mufflers was tested.

The authors recommend a tentative design for the Liberty 12-cylinder engine, that shown in Fig. 3, where air is supposed to pass through the inner tube to some extent aiding in cooling.—*National Advisory Committee for Aeronautics*, Report No. 55, preprint from Fifth Annual Report 1919, 38 pp., 27 figs. and numerous tables.

OZONE AIR CLEANING.

By E. S. Hallett.

Description of installations tested out in the public schools of St. Louis, Mo. The Head of the Hygiene Department of the Board of Education of St. Louis came to the Building Department with the complaint from one of the downtown schools that the air was so bad in some rooms that teachers threatened to resign on the advice of their physicians. The writer proposed to the Hygiene Department to test the application of ozone.

The ozone apparatus was set up in the air passage between the air washer and fan, and regulated to produce just sufficient ozone to be barely detected by the odor on entering the building, but not enough to make one conscious of an odor. The result was the actual disappearance of all the stuffy conditions and bad smells complained of. The teachers stated that the conduct of the children as to lessons and behavior was noticeably better. Colds and coughs nearly disappeared. No contagious diseases developed during the six weeks' trial, although the influenza was epidemic at this time. In fact, during the period of an influenza epidemic, the attendance in this school was 30 per cent higher than the general average attendance for this school.

The experiment was then transferred to a colored school having the plenum system with the Zellweger air-washing fan and with complete recirculation of the air. The ozone machine was set up just back of the fan, the ozone acting upon the water of the air washer as well. In this test the pupils and teachers were weighed weekly and a close inspection made by the staff physician of the Hygiene Department. About 75 per cent of the children gained in weight on an average of about one pound, about 5 per cent lost weight, while the rest suffered no change. Several very stout girls weighing about 170 lb. each lost from 5 to 8 lb. weight (total duration of test not stated). No indication of illness or discomfort was noted. No contagious diseases occurred in this school and colds were noticeably less.

The coal consumption was measured, and in comparison with days of equal outside temperature the coal used was almost exactly one-half.

Agar plates were exposed in a room filled with pupils and showed an average count of bacteria of 225, which was extremely low, indicating that the ozone had destroyed the active germs of the air.

These and other tests during a year's period indicated that ozone destroys all odors resulting from the respiration, bodies and clothing of the children, and produces a mild exhilaration resembling that of a sea breeze or the air on a morning after a thunderstorm. It appears from limited data to be a preventive of influenza, and it is believed that its introduction in ventilation would probably remove the necessity for open-air schools now common in most cities.

The maximum concentration should be too low to give an ozone odor, and if used up to this concentration is safe for ventilation. Persons not used to ozone in air must be employed for detecting the air, as the sense of smell for ozone quickly declines when exposed to it.

The writer developed a standard which may be used in determining in advance the proper concentration for any given volume of air movement or for a given number of occupants in a room.

This standard was developed after ascertaining that with a given voltage and with a given thickness of dielectric the amount of ozone generated was proportional to the number of brush discharge points of the generator.

The most satisfactory apparatus uses 4,000 volts alternating current from a static transformer, all included with the ozone generator unit, which uses a micanite plate dielectric 0.040 in. thick and aluminum points spaced approximately ½ in. apart. It was observed that 600 brush points made just enough ozone for 1,000 cu. ft. of air from the blast fan.

This test was with rooms filled with 45 to 50 children much below the average in cleanliness. For rooms occupied by fewer people, the brush points or voltage should be reduced. If conditions are to remain constant, some points should be disconnected, but with varying conditions a controller should be installed to regulate the voltage by taking taps out of the primary of the transformers.

Where the air is recirculated in whole or in part, the ozone must be cut down to the point where no ozone odor is noticeable. In fact, the revitalizing of the air of the average school room when recirculating 90 per cent of the air will be effectively done with half the maximum stated above. The writer believes that the delay in the use of ozone in ventilation has been due to trials made with too high concentration and to the absence of any information on a means of control.

The writer proceeds to show a heating system designed in the light of these tests. It has no air washer.—Paper presented at the Annual Meeting of the American Society of Heating and Ventilating Engineers, Jan. 27-29, 1920, under the title, "An Advance in Air Conditioning in School Buildings." Compare *Heating and Ventilating Magazine*, Vol. 17, No. 2, Feb., 1920, pp. 25-29, 1 fig.

POTS AND BOXES USED IN CARBONIZING.

By H. H. Harris.

While heat-treating furnaces and processes have been consistently developed in the last score of years the pots and boxes used in the cyanide and lead-hardening processes have changed very little.

The factors govern the service received from pots and boxes. They are—design, method of manufacture, and material. As regards design, the author states that while in some plants there have been considerable improvements, through the industry at large a great majority of carbonizing boxes are of a design as well adapted for packing soap as they are for carbonizing, which affects the results obtained in a very undesirable manner.

To be good a box must be designed to permit tight sealing with some refractory or other material, in such a manner, however, that the clay should not enter the box and mix with the compound. Proper dimensions of the box are also important. The thickness of the box should be light enough to prevent warpage and still sufficient to permit proper flow of metal in the casting.

Materials for pot and box manufacture may be grouped into six classifications: Cast iron, cast steel, pressed and rolled steel, "trick" materials, alloys and materials calorized.

Cast iron is both the cheapest first-cost material and the poorest. It oxidizes rapidly, gives a non-uniform service, becomes distorted easily, forms scale which mixes with the carbonizing compound and is likely to spoil the work, and finally is affected by the cyaniding mixtures.

Cast steel is generally much superior to cast iron. It costs about twice as much per pound, but may give much longer service. The principal objection to cast steel is that the grade of steel used for pots and boxes is usually of inferior quality, sometimes even semi-steel being offered for steel. The method of casting the pots and boxes is also often unsatisfactory.

Judging, however, from the average of various types and conditions studied in many of the largest plants in the country, the author does not believe that any material has shown on the average a uniformly longer life per dollar invested than cast steel with the exception of a nickel-chromium alloy which he refers to as "Q-alloy."

Pressed- and wrought-steel pots were quite generally used some time ago before the advance in price of this material. Its advantage is its light weight and consequent small heat consumption. Its disadvantages are its high price and the comparatively few shapes in which it can be secured. Some companies manufacture their own annealing boxes from wrought steel, riveting or welding them together. Some of these are said to give satisfaction in extreme temperatures, but not under general conditions. Wrought-steel riveted or

welded pots for cyanide, chloride or lead conditions have never been successful owing to leakage.

By "trick" materials, the author means products misrepresented by their makers or sold under a trade name which does not correctly indicate their nature. Alloys for heat-resisting purposes are a new development and may be said to be used in their infancy.

The latest development in the alloy field is a special nickel-chromium alloy, the analysis of which the author is not yet authorized to divulge. This material differs from nickel-chromium alloys on the market in that it retains many of the physical characteristics of the cold metal at a temperature of 2,800 deg. fahr. and rings like a bell when struck with a hammer at this temperature. This new alloy is known as Q-alloy, grade X.

The only true scale of value by which a user can judge most competitive production materials consumed in service is by comparing their life under service conditions with their initial cost, and determining how many units of service each renders per dollar investment. In computing pot and box cost a unit is a heat-hour, which is an hour in the furnace under heat. Cost per heat-hour is arrived at by dividing the number of heat-hours received into the initial cost of the pot or box; for instance, if a cast-iron box weighing 100 lb. and cost 5 cents per lb. runs 100 heat-hours, the cost is 5 cents per hour. A steel box at 12 cents per lb. should run at least 300 hours under the same conditions, making a cost to the user of 4 cents per heat-hour. Under certain circumstances parallel to this Q-alloy has been known to run 7,000 hours, making a cost to the user of 2 cents per heat-hour. Where an alloy affords a saving in cost per heat-hour it minimizes warpage and allows a thinner section to be used, thereby saving fuel in heating the box and its contents.

Thousands of tons of metal per annum are being consumed in the fires of heat-treating furnaces. This metal is paid for by companies every one of which could use the money so expended to the betterment of their product rather than writing it off in the profit-and-loss column and passing the tariff on to the ultimate consumer. American industry quite frequently puts up with undue waste to obtain production and perhaps the greatest waste in the metal-working industries, which can be directly attributed to ignorance and neglect, is the waste of metal consumed in the heat-treating processes. This waste can never be entirely eliminated, but it may be greatly reduced.—*The Iron Age*, Vol. 105, No. 11, March 11, 1920, pp. 729-731.

Progress in Mining and Metallurgy

Abstracts of Paper to be Presented at the Lake Superior Meeting, August, 1920

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

DETERMINATION OF PORE SPACE OF OIL AND GAS SANDS.

By A. F. Melcher, M.S., Washington, D. C.

A progress report on an investigation of the physical factors of oil and gas and especially of their sands, such as pore space, size of pores or permeability, retentivity, viscosity of the oil, temperature, pressure, thickness and area of the pay sand, water relations, and capillarity. The purpose is to determine as many of these physical factors as possible, and to ascertain the relations existing, directly or indirectly, between these physical factors and the production of oil and gas. As yet only pore space and size of grains of pay sands have been investigated, although an apparatus has been designed to determine the permeability of a sand to oil, water, or gas under definite drops of pressure between the entrance face and exit face of the sample.

In selecting a method for the determination of pore space, two objects were kept in mind: First, the method must not only be sufficiently accurate to be of a truly scientific nature but must also be rapid enough to justify its commercial use. Second, the method, to have as large a range as possible, must permit the determination of pore space of many types of samples of different composition and structure, with great range of size.

Conclusions are as follows: A method has been established that will determine the pore space of very small fragments of oil and gas sands and determine the pore space accurately. None of the pay sands in which oil was found, if the pore space was less than 10.5 per cent, were producing sands. A study of samples suggests the conclusion that production is dependent on both pore space and size of grains, other factors being equal.

CHARPY IMPACT TEST AS APPLIED TO ALUMINUM ALLOYS.

By E. H. Dix, Jr., M. E., M. M. E., Cleveland, Ohio.

The success of the Charpy impact test in the steel industry has led to investigation of its possible application to aluminum and its alloys. Results of a few preliminary tests made at the Lynite Laboratories of the Aluminum Manufactures, Inc., are given. Slow-bending tests were made duplicating the arrangement of the impact machine, on both notched and unnotched specimens of a series of copper-aluminum alloys.

Results are summarized as follows: The Charpy impact resistance of copper-aluminum alloys decreases with increase in copper content, within the limit of these experiments (12 per cent copper).

No direct relation has been discovered between the Charpy impact resistance and the more common physical properties. However, in general, for this series of alloys the impact resistance decreases as the yield point, tensile strength and hardness increase and the impact value follows more nearly the elongation than the "product of tensile strength by elongation," as is often stated.

The notch effect is very much less pronounced in this series of alloys than in steel. The ratio of unnotched to the notched resistance in the Charpy test varies from 2.4 to 4.8, the notched bar having one-half the breaking area of the unnotched. For steel bars having equal breaking areas, the unnotched bar offers four to five times as much resistance as the notched bar. The notched specimen was the same as used in these experiments, but the unnotched was of the shape that would be obtained by planning a notched bar to the root of the notch.

The slow-bending tests give the same order of results as the Charpy impact, but the ratio of energy absorbed in the slow-bending test to that of the Charpy test varies from 0.27 to 1.02. Captain Philpot of England has reported that for steel this ratio is so nearly constant that he was led to the following conclusion: "The notched bar test made in a pendulum testing machine is not essentially an impact test." The experiments reported on in this paper do not justify such a conclusion for these copper-aluminum alloys.

The ratio of maximum load of the unnotched bar to maximum load of the notched bar in the slow-bending test is very interesting. Since the strength of a beam varies as the square of its depth, the maximum load of the unnotched bar should be four times that of the notched bar if the notched bar were not further weakened by the "notch effect." This

ratio varies from 2.73 for pure aluminum to 4.44 for the 12 per cent alloy. This shows that the notch not only does not weaken pure aluminum but rather enables it to stand a proportionally higher load. For the 12 per cent copper alloy, the weakening effect is small.

These results indicate that the Charpy impact test is a satisfactory test for aluminum alloys. When making this statement, the author fully realizes the danger of judging a material by its Charpy impact value without full consideration of the other physical properties. For instance, we must learn the proper Charpy figure combined with a given tensile strength and elongation that will give the most satisfactory shock-resisting aluminum alloy, just as the steel crankshaft manufacturer now knows the proper combination of Charpy impact value and yield-point strength that will give the most satisfactory service.

NITROGEN IN STEEL, AND THE EROSION OF GUNS.

By H. E. Wheeler, C.Ch.E., Chicago, Ill.

The work described was carried out during 1917 and 1918 at the testing laboratory of Watertown Arsenal at the instigation of the Nitrate Division and later with the concurrence of the Cannon Section of the Ordnance Department, U. S. A. The experiments follow three principal lines of work: First, the effect of nitrogen under pressure on steel containers of various compositions at a red heat; second, the effect of decomposing ammonia on various alloy steels, iron and non-ferrous alloys; third, a new theory of the erosion of guns in respect to the effect of nitrogen in steel.

In the Haber process for the manufacture of ammonia from its elements, it is necessary to have nitrogen and hydrogen of 1500 lb. per sq. in. (105.5 kg. per sq. cm.) at a temperature of 500 to 600°C. The steel containers for these gases gave trouble by failing without apparent cause.

When the General Chemical Co. began to develop its method for the production of ammonia, it experienced the same difficulty and, knowing that the Haber process had solved the difficulty by the use of alloy steels, it made several small steel bottles of different compositions and kept them filled with these gases at this pressure and temperature until they failed. Four of these steel bottles were sent to this laboratory for investigation; they were a plain carbon-steel forging, a nickel-steel forging, a chrome-vanadium steel forging and a chrome steel-forging. The time of service was as follows: plain carbon steel, 4 mo.; nickel steel, 6 mo.; chrome-vanadium steel, over 2 yr.; chrome steel, 4 mo. When these containers were cut open and the cross-section surface polished, they showed an inside zone with a different luster from the rest of the metal. Upon etching, this zone was almost unaffected while the rest of the steel etched normally.

A few preliminary experiments on alloy steels indicated that a stream of ammonia passed over them for a long period of time, at about 650°C., gave an effect very similar to that observed in the cylinders described. High-pressure experiments with molecular nitrogen are difficult, dangerous, and take a great deal of time, so it was thought that a study of the effect of nascent nitrogen on various steels might throw some light on their general behavior and be a good method of elimination.

EROSION OF GUNS.

A study of the data on erosion shows that it has been customary to treat a comparatively small number of experiments with an intensive study of each, rather than to take the salient features from a larger number of experiments. The opportunity to take the latter course was presented during the war but, so far as the writer has been able to find out, no new facts regarding erosion were discovered by any of the governments participating. It is surprising to find that while almost all metals have been experimented with in so-called erosion experiments, only a very few have actually been tried in a gun; and even these have been tried only in a hit-and-miss fashion.

For this paper, erosion will be defined as the enlargement of the bore and obliteration of the rifling from any cause. Some of these causes are: The eccentric path taken by the projectile and the consequent pounding; the whip or vibration of long guns; the muzzle droop of long guns; mechanical wear or abrasion, from the passing of the projectile, gases, or unburned powder, etc.; protrusion of liners and consequent loss of metal within the bore; swelling of barrel (in small arms) due to lowering of elastic limit; cracking of bore surface due to the formation of a hard layer of low ductility. Only this last feature of erosion is dealt with.

To describe it briefly, even after the first few rounds, there is a noticeable hardening of the surface, which is selective in its formation. The microscope reveals it as a layer that remains bright on etching and exhibits no structure. The formation follows the driving side of the lands, preferentially, and eventually the entire land and groove and even the powder chamber and forcing cone are affected. The formation on the bearing surface of the land extends much farther down the bore than on any other point of the circumference. This layer is characterized by hardness and especially by its low ductility, so that it no sooner forms than it develops a network of fine hair-like cracks which make a characteristic pattern, the largest being in a plane perpendicular or parallel to the axis of the bore. The enlargement of these cracks, and the consequent roughening of the bore, is generally admitted to be one of the chief determining factors in the life of guns of large calibers.

STABILITY OF VARIOUS HICKORIES FOR VEHICLE MANUFACTURE.

The principal species of hickory are divided botanically into two groups, true hickories and pecan hickories. True hickories include shellbark, shagbark, mockernut, and pignut or black hickories. Pecans include bitternut, nutmeg, pecan, and water hickories.

The chief difference between true and pecan hickory, as shown by tests at the Forest Products Laboratory, is in toughness or shock-resisting ability. This is the property which is so valuable in wood handles and vehicle parts. In this property true hickories are far superior to the pecans.

The strength properties of pecan are somewhat in excess of those of oak or maple, and for such articles as handles and buggy spokes, carefully selected pecan is probably to be preferred to either of these two woods. In heavy wagon parts, such as axles, spokes and felloes, maple and oak are reputed to stay in place better than hickory. Except in case of extreme shortage of maple, true hickory and oak it would probably be inexpedient to use pecan hickory for these heavy parts.

The sapwood or white wood of hickory, which is usually preferred by the trade, is the better wood in young, thrifty trees; but in over-mature trees it is inferior to the heartwood. A red color does not necessarily make sound hickory unsuitable for vehicle stock.

A more useful criterion than color is the proportion of summerwood, or nonporous wood, in the annual growth rings. In hickory stock intended for the more exacting uses, the nonporous wood should form at least one-half and preferably three-quarters of the annual ring; and the remaining part should contain very few pores. A further precaution to be observed is that the nonporous part of the annual ring should be hard and flinty.

The best criterion of the strength properties of either true or pecan hickory is the weight of a cubic foot of the dry wood. This weight should not be more than 10 per cent below the average for true hickory; or not less than 45 pounds per cubic foot of oven-dry wood.

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CUTTING THE COCOANUT CAKE—PHILIPPINE NATIVES HAULING COCOANUTS TO THE MILLS. (SEE PAGE 404)

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OUR APPLE.

WHAT do we know about the planet we live upon? We have determined its shape; we have measured its size; we have estimated its weight; we have climbed its mountain peaks and delved into its ocean depths; we have winged our way up into the envelope of the atmosphere and soared far above the clouds, and we have bored far into the ground, but there are lofty heights that have not yet been scaled, profound depths that have not been sounded, and vast areas that have not yet felt the tread of human foot. Undoubtedly it is only a question of time when all these regions will yield to the zeal of the explorer. However, then we shall have but a superficial acquaintance with the earth. In some respects we know more about the sun than we do about our own planet. We have actually discovered elements on the sun before they were found here on the earth. At best our knowledge of the earth is not even skin deep.

The skin of an apple measures in the neighborhood of a hundredth of an inch in thickness. The apple—a large one—is, say, four inches in diameter. Enlarge it to the diameter of the earth and the skin will measure about twenty miles in thickness. What do we know about the skin of our apple?

The deepest well ever bored is on the Lake farm near Fairmount, West Virginia. It is a hole six inches in diameter, which was driven to a depth of 7579 feet, or nearly a mile and a half, before a slide of earth stopped further boring. The deepest mine shaft in the world is at Morro Velho, Brazil, which goes down to a depth of 6400 feet below the surface, or approximately one mile and a fifth. So far we have barely begun to gnaw through the skin of the earth. What do we know of the meat of this apple?

We assume that the center of the earth is hot, very hot indeed. Samples of the earth's interior are hurled out of volcanoes, or pour as molten lava from the lips of craters, but we can only guess at the depth from which this material comes. We doubt that the core of the earth is molten.

We know that as we dig into the earth the temperature rises, but the rise of temperature is not regular; it varies with different localities. In the Lake well referred to above a temperature of 168.6 degrees Fahrenheit was observed at a depth of 7500 feet. It is assumed that the boiling point would be reached at a depth of about 10,000 feet.

Because we know so little of the interior of the earth it has been suggested that explorations be conducted into the interior of the earth for the purpose of obtaining scientific information. Some years ago Sir Charles A. Parsons proposed that a shaft be dug to a depth of twelve miles. It was objected at the time that the enormous pressure of the earth would make it difficult, if not impossible, to dig such a shaft. When the aqueduct siphon was bored through solid granite under the Hudson River to a depth of 1200 feet special measures had to be taken to protect the workmen from large flakes of rock which were constantly breaking off with a snap like that of a pistol report. This flaking was due to the release of pressure on the rock which had been under enormous compressive strains for ages. Undoubtedly difficulties of that sort would be encountered in boring a twelve-mile shaft. It was even suggested that the surrounding pressure would actually close the bore. However, small scale experiments have been made with high pressures and temperatures which indicate that such would not be the case and it is probable that the full diameter of the bore could be maintained until so great a depth had been attained that the combined heat and pressure would render the rock plastic and cause it to flow into the bore. This would certainly not take place at a depth of less than thirty miles. No doubt the greatest obstacle to be overcome would be that of high temperature. Special cooling apparatus would be required to reduce the heat sufficiently to enable the workmen to perform their labors.

The subject is discussed by Sir Charles A. Parsons in the article on High Temperatures and Pressures on page 432. When he first proposed digging such a shaft he estimated that it would require about eighty years to complete the work. Since then excavating machinery and methods have been improved to such an extent that it seems probable that such a shaft could be sunk in thirty years.

The lessons that we should learn from such an undertaking would be of untold value to science. It is quite possible new light would be thrown upon the composition of chemical elements. We might learn something about the transmutation of metals in Nature's laboratory down in the bowels of the earth.

Not only would the shaft be of interest to science, but it is quite probable that it would prove of commercial value. Those who have bewailed the fact that we are fast exhausting our stores of coal and oil and have been holding forth a gloomy prospect for posterity may be reminded that there are vast stores of heat confined within the earth which have not yet been tapped. Even now some use is being made of the internal heat of the earth in certain volcanic regions of Italy, where the steam issuing from the ground is trapped and put to work. It has been proposed that bores be sunk into the ground to admit water which would be converted into steam, and then converted into mechanical work. There are untold stores of energy under our very feet waiting to be developed by future generations. Undoubtedly there are vast deposits of minerals still to be exploited and it may be that there are materials rich in value yet to be discovered and put into the service of man.

It is well worth our while to explore the skin of the apple we live upon.

Celestial Photography for Amateurs*

Excellent Results Obtained With Crude Apparatus

By Dean B. McLaughlin

As a rule, I believe that amateur astronomers have, on the whole, remained aloof from the field of celestial photography. This is probably not because they have no inclination to apply photography to their work, but because they do not realize the full power of their instruments. They are apt to think that their telescopes can accomplish nothing in this line. It is the purpose of this article, therefore, to show just what results can be obtained with the smallest and crudest of apparatus. The reader should bear in mind that the largest instrument I have ever used for photography is a 2¼-inch telescope of 34-inch focal length.

In February, 1915, I experimented with a No. 2 Brownie camera and found that with the instantaneous exposure of its shutter, it was possible to obtain very good pictures of the moon. Although only a millimeter in diameter, these images show all the naked-eye details of the moon. I then constructed the lunar camera with which the accompanying photographs were obtained (Figs. 2 and 4).

This is a light-proof wooden box about five inches square and six inches deep (Fig. 1). The front of the box is double. In the first thickness of wood there is a hole large enough to admit the eye-piece end of the telescope. The next thickness is pierced with a hole as large as the rear lens of the eye-piece. Back of this hole is the shutter, which consists of a slip of cardboard with a hole in it. The exposure is made by allowing this hole to pass by the eye-piece. This shutter is operated by a rubber band, which is perhaps the simplest and most efficient shutter spring for such a camera. The back is open and carries a ground glass screen. There is an opening to accommodate a four by five plate-holder. The principle employed in this apparatus is that of *projection*, i.e., the image of the moon is projected on the plate, just as the solar image is projected on a screen for the study of sunspots. (See Fig. 1).

FIG. 1. SMALL TELESCOPE FOR LUNAR AND SOLAR PHOTOGRAPHY

For some time I used a small telescope of the type popularly known as a "spy-glass." A lunar image about 22 mm. in diameter was obtained with an exposure of half a second. The negatives thus taken were rather thin and did not show objects on the terminator. Later, using the 2¼-inch telescope, denser negatives were obtained somewhat smaller than the first. These showed many details on the terminator, but this topic will be discussed later.

The telescope and camera are securely mounted on a board. It may be propped against any handy object. Of course, with this arrangement, it is impossible to follow the moon. The apparent motion per second, due to the rotation of the Earth is:

$$m'' = 15'' \cos \delta$$

where δ is the declination of the moon. Since the moon is never as much as 29° from the Equator, its minimum motion is more than 13″ per second. Therefore, with the telescope at

FIG. 2. SOLAR ECLIPSE AT NEW YORK, JUNE 8, 1918. 11H. 06M. G.M.T.

rest, an exposure of more than half a second would materially injure the smaller details. The farther the plate is from the eye-piece, the larger will be the image obtained; but the larger the image, the thinner will be the negative. From experience I have found that it is best to make the diameter of the image *one-third of the aperture of the telescope.* Thus, with a 2¼-inch instrument, I make the image of the moon about ¾ inch in diameter.

When photographing the sun, I use my "spy-glass" and obtain a much larger image. My greatest difficulty has been in obtaining a short enough exposure. When taking a solar photo, the shutter is allowed to drop as fast as the rubber band can move it. When photographing the moon, it is lowered slowly with the hand.

The prints can never do justice to the original negatives. The nearest to perfect prints are a few lantern slides which a friend made from my negatives. To give an idea of the delicate details obtained with this seemingly insignificant apparatus, I will summarize a catalogue which I made of the craters found on the plates by careful microscopic examination. On first examination of 32 plates, a total of 51 craters, whose names I knew, were found. A second examination resulted in listing 11 more. These craters ranged from Clavius down to craters twenty miles in diameter. Many unnamed craters only ten miles in diameter were found. Some appeared only once, but many were found on four or five plates. In addition to this, a photograph of Venus in the crescent phase was obtained. The crescent was distinct under the microscope. The image was only a third of a millimeter in diameter.

Since my telescopes are not mounted equatorially and have no driving clock, it would appear that the photography of the stars is impossible with my equipment. However, I was able to convert my tripod into an equatorial mounting by re-adjusting the legs. As for the driving clock, the hand is a fair substitute.

*Reprinted from *Popular Astronomy,* February, 1920.

The stellar camera (Fig. 3) consists of a cardboard box, at the front of which is a common *reading-glass.* The shutter is a sheet of cardboard before the lens and is raised and lowered by means of two strings. The camera is strapped to the tube of the telescope. It is evident that if a star be

FIG. 3. STELLAR CAMERA MOUNTED ON TELESCOPE TUBE

followed so as to remain in the field of the telescope, that star will occupy a nearly fixed position on the sensitive film. To keep it as accurately in one place as is possible with such an instrument, a pair of cross-threads is placed between the lenses of a negative eye-piece. The star image is thrown out of focus so as to obtain a small disk on which the cross-threads stand out clearly. A Premo film pack is used because small enough plates could not be obtained.

The operation with this instrument is as follows: First, the film pack is placed in position, the focus having been found. Then a bright star in the region to be photographed is selected and its image brought to the intersection of the cross-threads. Then, *and not until then,* the shutter is opened and the star is followed so as to remain at the intersection of the threads. If by any chance it escapes from the field, the shutter is closed at once. The following of the star in this manner is nervous work. I have never been able to continue it for more than ten minutes. A total exposure of half an hour or more should be given for most photographs.

Of course there are numerous disadvantages. First, if the telescope is not accurately mounted as an equatorial, the star may leave a trail, although this will never be very long. Secondly, the reading-glass lens is not corrected for spherical aberration. If a camera with a wide lens, such as the Graflex, is available, it should be used by all means. If a driving clock is used, the photographer should, nevertheless, remain at the eye-piece to correct any irregularities of motion. Figs. 5 and 6 were obtained with the apparatus described above.

The negative of Fig. 5 shows more than 20 stars and that of Fig. 6 shows over 40.

Lastly, we come to the use of the hand camera. The two series of photographs shown in Figs. 7 and 8 were obtained by leaving the camera in one position until it became necessary to start a new row. At intervals of five minutes or so, photographs were taken. Fig. 7 was over-exposed. Fig. 8 was taken with the lens stopped down to little more than a pinhole and giving an exposure of 1/50 second. Both were taken with a No. 2 Folding Brownie.

Concerning the results that may be obtained with various instruments, I will say that I do not believe it beyond the power of a three-inch telescope to obtain recognizable photographs of Saturn and his rings, provided the telescope has a good driving clock and is equatorially mounted. Other good objects for such an instrument would be Jupiter and his satellites and Venus, in all her phases. Two or three minutes' exposure should be given for Jupiter's moons.

There are a few points which it will be well for a beginner in celestial photography to bear in mind:

1. Don't sacrifice density in the negative, for the sake of obtaining a large picture.
2. Don't try to photograph the moon through a thin film of cloud. The cloud absorbs a large proportion of the blue end of the spectrum.
3. The same applies to any heavenly body when near the horizon.
4. Remember that the intensity of light varies inversely as the area over which it is spread.

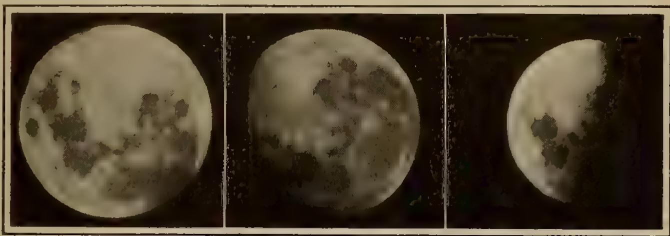

FIG. 4. THREE PHOTOGRAPHS OF THE MOON

5. Don't expose more than half a second unless a driving clock is used.

I have found the Stanley dry plate, manufactured by the Eastman Kodak Company, perfectly satisfactory for all my work.

INTERNATIONAL COMMITTEE ON STELLAR PARALLAXES.

At the initial meeting of the International Astronomical Union, held in Brussels last July a committee on Stellar Parallaxes was appointed. All institutions in the United States which are actively engaged in stellar parallax work are represented in the membership of this committee and thus the corresponding committee of the American Astronomical Society appears to have become superfluous.

FIG. 5. ALTAIR AND VICINITY. EXPOSURE 25 MINUTES

FIG. 6. PHOTOGRAPH OF X AND Y CYGNI. EXPOSURE 10 MINUTES

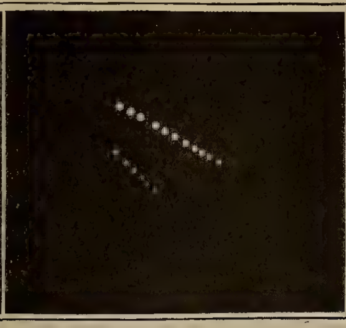

FIG. 7. SERIAL PHOTOGRAPH OF LUNAR ECLIPSE, JAN. 7-8, 1917

FIG. 8. SERIAL PHOTOGRAPH OF SOLAR ECLIPSE, JUNE 8, 1918

Will o' the Wisp—Ignis Fatuus—Irrlichter—Feux Follet

Interesting Records of This Curious Phenomenon

By Rich D. Whitney, Assoc. Prof. of Electrical Engineering, Syracuse University

THE phenomenon known as the Will o' the Wisp is one of whose origin little is known and of whose occurrence few authentic records are available. The appearance of this phenomenon is of such a nature as quite to unnerve the ordinary observer and cause his imagination to run riot with the result that few facts are really known. Among the ignorant and superstitious, the will o' the wisp is thought to be due to the evil one and its antics often seem to bear this out.

In getting together the material for this article, the author has searched out all probable sources of information on the subject to be found in English, French, Italian and German. The absence of the subject from scientific writings is conspicuous. The longest treatise on the subject was found in the American Encyclopedia which was published in 1808 at a time when the fluid theory of electricity was the most accepted one.

Professor Besel, a German scientist, writing in *Annalen der Physik*, Vol. XLIV, page 366, tells of an experience which he had in the neighborhood of a great swamp in the Duchy of Bremen along the river Wörpe, December 2, 1807. The phenomenon was observed by him in the morning hours of a dark, calm night after a light rain had fallen occasionally throughout the night. The professor was aboard a boat and learned that the phenomenon was common in that locality but of sufficient distance away so that the skipper of the boat was not disturbed by it. The place of occurrence was a peat bed which was continuously dug over by the peasants of the neighborhood. Numerous little flames seemed to stand over water puddles among the bogs. After glowing for some time they would disappear. The color of the flame was somewhat bluish like that of impure hydrogen gas. Their light power must have been inconsiderable as he was unable to see that the ground in the immediate vicinity was noticeably illuminated or that the large numbers of them spread abroad any noticeable light. Professor Besel estimated the number of such flames visible at any time as about one hundred and their duration about fifteen seconds. Some of the flames seemed fixed, others moved horizontally and whole groups were observed to float about like flocks of flying birds. The flames seemed to remain in the lower portions of the bogs. The professor suggested that an expedition be formed to investigate the locality and the appearance of the "Irrlichter" but no such expedition was later recorded.

In a translation from the Italian, the following incidents were recorded: A certain painter was passing along the streets of Bologna at night when he saw a fiery ball come out from between the flag stones of the street almost between his feet, run along the ground, arise to some height and vanish. He felt the heat on his face as the ball passed near him. He reported the phenomenon to another gentleman who made an extensive study of the locality and the appearance of the will o' the wisp, going from place to place and making lengthy observations. He observed on both clear and cloudy nights. This gentleman said that the phenomenon was generally supposed to be connected with decaying animal matter and to originate many times in grave yeards. He remained at church yard entrances a great deal but never saw one there. These investigations were carried out in late autumn, a time when this fiery phenomenon happens to show itself more frequently than at any other time, according to the published reports. He found this to be true and attributed it to the quick changes in the depth of the atmosphere which allowed the gases held in the earth to respond to their natural elasticity and find an exit. He observed only three will o' the wisp phenomena and each on a different night.

The first came out of the earth, arose to a height of ten to fifteen feet and with a slight report disappeared. The second moved horizontally, was followed by the investigator until it was borne over a river by the wind and disappeared. The third brought the opportunity for an experiment which the observer had tried to make before but without success. He carried out the experiment in the parish of St. Domino near the little church "Ascension," about two miles from Bologna. This church was near a brook in which years before three silver offering bowls of beautiful old Roman work had been found. This region was especially rich in will o' the wisp. The peasants thereabouts were superstitious and believed these flames to be the burnings of souls. He had spent several evenings there in vain but on the night following what is called there the "Northern Light Night" in October, he was rewarded. He was tired from traveling and stopped at the house of the peasant in whose field the lights were said to appear. He opened the window which looked out upon the field and toward eleven o'clock the much desired light appeared. With a stick on the end of which was fastened a piece of easily ignitable oakum, he rushed to the place while the peasants flocked to the windows and doors. When within about twenty steps of the light he stopped to observe it. It had the form and color of an ordinary flame but had a light smoke. It was almost five inches thick and moved slowly forward from the south to the north. Upon his approach, it changed its direction, increased its distance from him and arose. By a very quick motion with the stick, he was able to pass the oakum through the flame and the former instantly ignited and by swinging it above his head, the peasants distinguished the flame from that of the phenomenon. Soon the will o' the wisp went out at a height of twelve to eighteen feet. It reappeared (if it was not another) but was much smaller and at a distance. The observer ran toward where it appeared but it went out and he was never able to see any others in that locality again. The ashes of the oakum did not smell as phosphorous does but had a very peculiar and strong odor which he thought was not unlike ammonia and sulphur.

Herr Vogel, an astronomer of Leipzig, observed this phenomenon twice. He first saw the will o' the wisp in Saxony on a dark rainy night of September, 1849, when he was journeying between two cities with friends. Two or three hundred feet from the road there was a swampy tract of land on which little flames were to be seen. The neighboring peasants declared this phenomenon to be common in that locality. In November of the same year he observed will o' the wisp in great quantity just outside of one of the gates of Leipzig. He went to the palace to investigate on a cold, bright evening. The ground on which the flames appeared was not very large, was damp and had been recently threaded with small ditches. After some time he saw a faint light in one of these ditches and saw a little flame about as bright as the glow of a lightly rubbed match gives out, and its brilliancy very similarly increased and decreased. It came and went with a period of about three seconds. This he observed for several minutes and was able to detect no odor or smoke. The flame lighted about three inches of the bottom of the ditch and was about one inch in height. Herr Vogel believed the phenomenon exactly like that he had previously seen except that in the first case the flames were much more numerous so that they had almost the appearance of moonlight on water in motion. He could detect no motion of the flame but when one went out and another came in its place it had the appearance of motion. A railroad guard told Herr Vogel that a quantity of glow worms had recently covered that ground.

From the French Encyclopedia, some of the following facts were taken: "Will o' the wisp are irregular lights which can be seen plainly at night around cemeteries and marshy places. The will o' the wisp has the aspect of a flame terminated by an aigrette which resembles the crown of a bird. It is visible especially in the autumn at calm times. This apparition is an object of fright for the peasants who believe they see a soul in pain. All contemporary works consider this phenomenon a luminous exhaling and the chemists are of the same mind. According to the latter the phenomenon proves organic matter in decomposition which gives off large bubbles of hydrogen phosphorous gas which is rendered spontaneously inflammable in the air by a small quantity of hydrogen phosphorous liquid. This explanation seems true as to the substance of the will o' the wisp as witnessed by the odor of phosphorous which the phenomenon leaves for some time after it has disappeared but does not coincide exactly with the facts. In reality the will o' the wisp will burn for ten, twenty or thirty seconds and rarely for several minutes and does not produce smoke, set things on fire, or even heat the herbs on which it rests. It must necessarily be admitted that, in the gas which makes up the 'feux follet,' the proportion of hydrogen phosphorous liquid is very slight to cause the spontaneous flaming up in the air and also that the phenomenon shines by phosphorescence only."

Another occurrence of these phenomena was reported as having occurred on Sunday, December 22, 1839, between five and nine o'clock in the evening on the streets of Fontainbleau in France. The weather was calm and rainy and phosphorescent flames arose from muddy puddles in many streets of the city and produced upon leaving the water a crackling noise. Wherever these flames were observed, the air seemed to be filled with a thick phosphorous smoke. Stirring the water in the puddles increased the number of flames which appeared.

From the American Encyclopedia the facts given in this paragraph were obtained: "Benighted travelers are sometimes said to have been misled into marshy places by the will o' the wisp which they thought were candles at a distance. The will o' the wisp are frequent about burying places and dung hills and certain countries are remarkable for the occurrence of this phenomenon, especially Italy, Spain and Ethiopa. It avoids the approach of anyone and flits from place to place as if animated. A certain Dr. Derham was able to get so near to a will o' the wisp that he had a very advantageous view of it. This was in some boggy ground between two rocky hills. It was a dark, calm night and he was able to advance within two or three yards of it. It appeared as a complete undivided body of light so that it could not have been occasioned by insects, and it kept dancing about a dead thistle. On his near approach it jumped to a new place and kept flying before him as he moved."

Monsieur Baccari learned that two of these lights appeared in the plains about Bologna, one north, the other south of that city and were to be seen almost every dark night. One of these appeared to a gentleman of his acquaintance as he was traveling. It moved constantly before him for about a mile and gave a better light than a torch. Both of these lights were reported as giving a very strong light and were constantly in motion. Sometimes they would rise, sometimes sink, but as a rule would hover about six feet above the ground. They would also disappear frequently and suddenly reappear in some other place. They differed also in size and shape, sometimes spreading wide, and then contracting, sometimes breaking into two parts and then joining again. They would at times appear like waves, at others sparks would seem to fall from them. They were but little affected by the wind and in wet and stormy weather they were frequently observed to cast a stronger light than in dry weather. They were also observed more frequently when snow lay upon the ground than in the hottest summer. The ground near Bologna where the largest of these lights was observed is a hard chalky soil mixed with clay, which retains moisture long, but breaks and cracks in hot weather. On the mountains where the soil is more loosely held together the will o' the wisp were not seen as often but seemed to choose regions near rivers or brooks.

Another record given by M. Baccari is as follows: "An intelligent gentleman traveling in the evening between six and nine o'clock on a mountainous road about ten miles south of Bologna, perceived a light which shone very strangely upon some stones near water. In size and figure it had the appearance of a parallelopiped about one foot in length and half a foot high, the longest side being parallel to the horizon. Its light was so strong that he could see by it part of the neighboring hedge and the water in the river; only in the east corner of it the light was rather faint and the square figure less perfect, as if it was cut off or darkened by the segment of a circle. On examining it a little nearer, he was surprised to find that it changed gradually from a bright red to a yellowish, and then to a pale color in proportion as he drew near; and when he came to the place itself it quite vanished. Upon this, he stepped back and not only saw it again but found that the farther he went from it the stronger and brighter it grew. When he examined the place of this luminous appearance, he could perceive no smell or any other mark of fire." Another gentleman informed M. Beccari that he had seen the same light five or six different times in spring and autumn and that it always appeared of the same shape and in the very same place. One night in particular, he observed it come out of a neighboring field to settle in the usual place.

A very remarkable account of the will o' the wisp is given by Dr. Shaw in his "Travels in the Holy Land." It appeared in the valley of Ephraim and attended him and his company for above an hour. Sometimes it appeared globular or like a candle flame; at others it spread to such a degree as to involve the whole company in a pale inoffensive light; then contracted itself and suddenly disappeared, but in less than a minute it would appear again; sometimes running swiftly along, it would expand itself at certain intervals over more than two or three acres of the adjacent mountains. The atmosphere from the beginning of the evening had been remarkably thick and hazy; and the dew as they felt it on the bridles of their horses was very clammy and noxious.

Similar lights are seen skipping around the riggings of ships at sea under similar weather conditions according to Dr. Shaw. We are told of one which appeared about the bed of a woman in Milan, surrounding it as well as her body entirely. This light fled from the hand which approached it but was at length entirely dispersed by the motion of the air.

Scotland's Elf's candles may be of this nature. These are supposed, upon appearance, to prophesy a death and have been known to set fire to grain stacks. They are a great terror to the people. They will avoid a drawn sword or sharp pointed iron instrument and from that we reason that they are electrical phenomena.

The American Encyclopedia also speaks of Sir Isaac Newton's calling the will o' the wisp vapor shining without heat and maintaining that it is as different from flame as shining rotten wood is different from red hot coals. The author then goes ahead to prove, to his satisfaction, that the whole phenomenon is a result of the "electrical fluid."

After considering the foregoing statements, we are led to the conclusion that the phenomenon has not as yet been satisfactorily explained. The flames seem to set fire to themselves as does phosphated hydrogen or Marsh gas. They seem to be peculiar to certain localities and common at those places. It would seem that the ability of the will o' the wisp to ignite other material with which it comes in contact depends upon its volume. The brightness, warmth, smoke and odor may in large quantities become evident while the same may be wanting in small amounts. On account of the feeble light of the flames as usually observed, the will o' the wisp might be thought of a simply phosphorescent gas if it were not for the experiment of setting fire to the oakum by it.

External Galaxies*

Are There Other Stellar Systems Similar to Our Own?

By Harlow Shapley

IN the present state of astrophysical knowledge, the problem of the existence of external stellar systems similar to our Galaxy reduces almost immediately to the problem of the status of spiral nebulae in the sidereal universe. In treating this question we must deal primarily with the "island-universe" hypothesis of spirals—an interpretation of long standing, which at the present time has many adherents and appears to be growing in general acceptance.[1]

The recent work on star clusters, in so far as it throws some light on the probable extent and structure of the galactic system, justifies a brief reconsideration of the question of external galaxies, and apparently leads to the rejection of the hypothesis that spiral nebulae should be interpreted as separate stellar systems. During the last two or three years a considerable amount of observational material bearing on the problem has come to hand, much of which was either not known or not fully considered by previous writers on the subject.

Four classes of objects, other than spiral and closely associated nebulae, have at times been suggested as possible external galaxies, the first three of which may be dismissed as no longer open to such interpretation: (1) *Large star clouds of the Milky Way:* the affiliation with the galactic region and its characteristic population shows them to be a fundamental part of the galactic system; (2) *The Magellanic Clouds:* the apparent magnitudes of their short-period variable stars determine definitely the order of the distance and size of these detached stellar systems, and prove them to be small in comparison with the galactic system;[2] (3) *Globular clusters:* those so far discovered are recognized now as dependents of the galactic system, although in many respects they are miniatures of the Galaxy and apparently for the most part are external to the regions where most of the galactic stars are found; (4) *Various peculiar nebulae and nebulous stars:* concerning them little is known, but in most cases they are to be classed with the ordinary gaseous nebulae (which are clearly associated with the Milky Way), or with peculiar types of individual stars, or with the faint spirals.

OUTLINE OF EVIDENCE BEARING ON THE "ISLAND UNIVERSE" HYPOTHESIS.

The relation of the spirals to the galactic system is not so easily disposed of as the cases considered above. In support or in partial support of the hypothesis that spirals are external stellar systems arguments based on the following four points may be advanced:

(*a*) Distribution with respect to the galactic plane, assuming obstruction of light in and near the Milky Way.[3]

(*b*) High radial velocities.

(*c*) Certain spectral characteristics.

(*d*) Some evidences of great distance.

Less definite propositions that may be ranged on this side of the question are:

(*e*) Improbability of a single galactic system in the sidereal universe:

(*f*) Physical appearance of a few of the spirals.

(*g*) Resemblance of structure in spirals to hypothetical spiral structure of the Milky Way System.

In the light of recent studies of nebulae and the galactic system the arguments founded on the seven foregoing points do not appear to establish the stellar interpretation; and none of them appears to be particularly troublesome for the hypothesis that the spiral nebulae are not external stellar systems. Many of these arguments in fact, are better interpreted according to this alternative theory that spiral nebulae are truly nebular objects.

Five additional points, which are apparently of much weight, and, taken together, seem decidedly unfavorable to the stellar interpretation of spirals, are as follows:

(*h*) New conception of the dimensions of the galactic system.

(*i*) Measures of internal motion in spiral nebulae.

(*j*) The occurrence of novae in spirals and their magnitudes at maximum.

(*k*) The systematic nature of the radial motions of spirals.

(*l*) The probable dependence of their distribution on galactic position.

Some of the foregoing are not completely independent of each other.[4] Four further points of less weight that may be suggested as opposed to the "island universe" theory are:

(*m*) The possibility of formulating a fairly satisfactory nebular theory of the spirals.

(*n*) Directly measured parallaxes.[5]

(*o*) The data of proper motion relative to mean distances and drifts.

(*p*) The apparent absence of a central nucleus in the galactic system.

REMARKS ON THE PRINCIPAL POINTS FAVORING THE "ISLAND UNIVERSE" HYPOTHESIS.

a and *l*. The well-known avoidance of low galactic latitude by spiral nebulae, and the progressive but irregular concentration to the galactic poles, is most naturally taken as evidence that the distribution of spirals and galactic stars is to a certain extent complementary; therefore, that the spirals are dependent and subordinate factors of the general system. It would be difficult indeed to believe that external and independent stellar "universes" could exhibit such striking relations to our particular stellar system when, in addition to this apparent dependence of distribution of galactic latitude, we also note: first, that the avoidance by spirals (particularly by the brighter ones) is greatest in the direction of the galactic center where the stars, globular clusters, planetary nebulae, etc., are most numerous, and that the avoidance is least in the northern hemisphere where the Milky Way is the thinnest and globular clusters are totally absent; and, second, that the radial velocities observed are not random, but have a definite relation to the galactic system and perhaps even depend on the angular distance from an apical point in or near the Milky Way.[6]

On the other hand, Campbell,[7] Curtis,[8] and others have

*From the *Publications* of the Astronomical Society of the Pacific for October, 1919. Reprinted in the *Journal of the Royal Astronomical Society of Canada*, December, 1919.

[1]Among special discussions of the theory, three should be mentioned: an article by Puiseux, "Spiral Nebulae," *Revue Scientifique*, April 6, 1912; Crommelin's paper "Are the Spiral Nebulae External Galaxies?" *Scientia*, Vol. 21, p. 365, 1917 (reprinted in the *Journal of the Royal Astronomical Society of Canada*, Vol. 12, 33, 1918); and the recent address by Curtis, "Modern Theories of Spiral Nebulae," *Journal of the Washington Academy of Sciences*, Vol. 9, 217, 1919. In all of these the evidence is held to be favorable to the "island universe" theory. The arguments reviewed and extended by Curtis are so fully and clearly expressed that they may be taken as presenting the case for the stellar interpretation of spiral nebulae. The alternative theory that the spirals are not stellar has been maintained little, if at all, in recent years.

[2]*Mt. Wilson Contr.*, No. 151, pp. 20 and 25, 1917; No. 152, p. 2, 1917.

[3]*Cf.* Curtis, *loc. cit.*, p. 225.

[4]For instance, the value of *j* may involve a partial acceptance of *h*.

[5]van Maanen, *Mt Wilson Contr.*, No. 158, 1918.

[6]*Mt. Wilson Contr.*, No. 161, Section VII, 1918. Cf. also reference below to work by Wirtz.

[7]*Science, N. S.*, 45, 531, 1917.

[8]*Loc. cit.*

THE GREAT NEBULA IN ANDROMEDA

It is estimated that it takes eight years for light to travel from one end of this mass to the other. (Photograph taken at Yerkes Observatory.)

proposed that spirals may actually be distributed at random, and that the apparent distribution with respect to the Galaxy can be explained by assuming that obstructing matter encircles the galactic discoid—dark occulting nebulosity analogous to that observed in the peripheral equatorial regions of many spiral nebulae. Patches of dark nebulosity certainly exist in the galactic system, at no great distance from the Sun, and it is quite possible that the apparent avoidance of the lowest latitudes by globular clusters is due to such material.[9] Spirals in the galactic plane beyond the confines of our system would be occulted as readily as globular clusters. In general, the observed distribution could be secured by liberal use of the hypothetical encircling opaque material.

The region avoided by spirals, however, particularly in the southern hemisphere, is many times wider than that avoided by globular clusters. A great area of the southern sky (well out of the Milky Way)[10] is quite transparent both to near and to extremely distant globular clusters, but it is practically devoid of spiral-nebulae sufficiently bright to have been observed. We must conclude, it appears, either that the spirals, whether near or distant, do not exist in that direction, or that there is a most remarkable arrangement of obscuring patches that eliminates all spirals but leaves a normal distribution of globular clusters.[11]

b. A few years ago Slipher's discovery that spiral nebulae as a class have extraordinary high radial velocities gave new life to the theory that these objects are distant stellar systems.[12] The average motion of the various types of stars and nebulae has been contrasted many times and the argument advanced that, since all galactic objects have reasonably small velocities, these peculiarly high values should therefore be attributed to separate "universes." During the last few years, however, this supposed isolation of the spirals has been altered. While their average radial velocity exceeds 500 km/sec, it is less than 400 km/sec for one-third of them. A number of galactic stars are now known with space velocities equal to or in excess of 400 km/sec. With the extension of the investigations of proper motion and radial velocity to the fainter magnitudes many high stellar velocities are being found.[13] Many globular clusters,[14] which are certainly subordinate to the galactic system, have radial velocities between 100 and 300 km/sec, and the great Magellanic clouds[15] also appear to have very high velocities of recession. Hence this argument of peculiarity in velocity seems no longer an important one for the "island universe" theory. High speed is not a condition impossible of production by the forces inherent in our galactic system.

c. The integrated and nuclear spectra of spirals are predominantly of a stellar type—usually resembling class G or K. With small dispersion the composite spectrum of a mixed group of stars, such as a globular cluster or a galactic system, would appear much the same. On the other hand bright lines are also found occasionally, and Seares's preliminary work on the distribution of color would indicate a much bluer spectral type for the nebular condensations in a spiral than for the nucleus.[16]

The analogy of the absorption spectrum of spirals with the composite spectrum of a stellar system cannot be carried very far, however, until higher dispersion has been used. We should remember that for many years stars differing so enormously in density, volume, and mass as the giant and dwarf eclipsing binaries of type G were classed together without question. Sidereal bodies in extremely different physical states obviously may give closely comparable spectra on the small dispersion that has been used for spiral nebulae.

d and *f*. With one or two possible exceptions the secondary nuclei in spiral nebulae are so distinctly nebulous that they cannot be considered individual stars. Even in Messier 33, probably the most conspicuously nucleated of the brighter spirals, it is easy on large-scale plates to distinguish between the superposed stellar images and the "softer" nebular condensations. It is possible, however, to see a resemblance of these diffuse nebulous objects to extremely distant stellar clusters,[17] but unless we introduce further unverified assumptions the analogy breaks down when the observed colors are intercompared.

EVIDENCE UNFAVORABLE TO THE "ISLAND UNIVERSE" HYPOTHESIS.

The observational and theoretical evidence against the stellar interpretation of spiral nebulae has already been discussed in various earlier papers on clusters,[18] in the present article space will be taken for only a brief summary of the arguments.

h. Formerly we compared any hypothetical external galaxy with a stellar system supposedly about 10,000 or 20,000 light-years in diameter. Recent studies of the galactic system indicate that its greatest diameter is not less than 300,000 light-years. This newer conception greatly embarrasses the interpretation of spirals as stellar organizations of a size comparable to that of the Galaxy. To be linearly as great as this, though angularly small, demands a distance from the Earth, even for the spirals of largest angular size, that would completely discredit many observational results. For example, if any bright spiral of 10′ greatest apparent, diameter has an actual diameter directly comparable with that of the galactic system, its distance must be greater than a hundred million light-years.

i. Under such circumstances the measures of internal motion by van Maanen, Kostinsky, and Lampland, would need to be summarily rejected. For instance, van Maanen's[19] careful measures of the nebulous points in Messier 101 would indicate rotational velocities greater than the velocity of light if that spiral is held to be even one-fifth as large as our Galaxy now appears to be. Similarly, the systematic drift derived by Wirtz[20] from a study of several hundred spirals, and the average proper motions suggested by the studies of Wirtz and Curtis[21] would indicate appalling velocities in space—quite irreconcilable with the spectroscopically measured velocities of translation and rotation.

j. Moreover, if in real dimensions spiral nebulae were analogous to our galactic system, the absolute magnitude of the novae in spirals would far transcend any luminosity with which we are acquainted, and would be at direct variance with present results on intrinsic stellar brightness. For at the distance computed above the absolute magnitude of a nova of the sixteenths apparent magnitude would be —16, nearly two hundred thousand times as bright as the novae of the galactic system for which van Maanen has determined the absolute luminosities.[22] An upper limit to the intrinsic brightness at-

[9]Shapley, *Proceedings of the National Academy of Sciences*, **5**, 344, 1919.

[10]Between galactic latitudes

[11]A third explanation that spirals, as compared with globular clusters, are very near to the solar system cannot be accepted in the face of other evidences of distance.

[12]That the large line-displacements in the spectra of spiral nebulae should be attributed to motion in the line of sight appears to be assured by a consideration of the following points: (1) The displacements are both positive and negative; (2) the appropriate relation of shift to wave-length is observed; (3) orbital motions in eclipsing binaries occasionally show displacements of the same order of magnitude; (4) in linear velocity the rotation observed spectroscopically in some spirals approaches the velocity in the line of sight.

[13]Adams and Joy, *Mt. Wilson Contr.* No. 163, 1919 *cf.* Wolf's frequent notes on large proper motions in recent velumes on the *Astronomische Nachrichten.*

[14]*Mt. Wilson Contr.*, No. 156, p. 12, 1918.

[15]R. E. Wilson, *Proc. Nat. Acad. Sci.*, **1**, 183, 1915.

[16]*Mt. Wilson Communication*, No. 36, 1916.

[17]*Publications Astr. Soc. Pac.*, **29**, 217, 1917.

[18]*Ibid.*, **30**, 42, 198; *Mt. Wilson Contr.*, No. 157, p. 1, 1918, and No. 161, Sections VII and VIII, 1918.

[19]*Mt. Wilson Contr.*, No. 118, 1916.

[20]*Astronomische Nachrichten*, **203**, 197, 293, 1916: **204**, 23, 1917; **206**, 109, 1918.

[21]*Pub. Ast. Soc. Pac.*, **27**, 217, 1915. In subsequent references Curtis has stated his lack of confidence in the reality of the observed proper motions. *Jour. Wash. Acad. Sci.*, 9, 221, 1919. The average time interval between first and second observations is 13 years and 40 years respectively, in the investigations by Curtis and by Wirtz.

[22]*Cf. Pub. Ast. Soc. Pac.*, **31**, 234, 1919.

tainable by stars is suggested by recent observational and theoretical work, and this limit is much fainter than —16. The study of globular clusters, for example, has yielded sufficient knowledge of the luminosity of more than a million stars to show that not one is within ten magnitudes of this enormous brightness. The luminosity of about 2,000 stars of the solar environs is now known, and probably none is even a ten-thousandth as luminous as absolute magnitude —16. Hence stellar luminosities of this order seem out of the question, and accordingly the close comparability of spirals containing such novae to our Galaxy appears inadmissible.

Let us abandon the comparison with the Galaxy and assume an average distance for the brighter spirals[23] that will give a reasonable maximum absolute magnitude for the novae. Then the measured internal motions also become reasonable and in good agreement with spectroscopically determined rotational velocities; likewise the distances become reconcilable with the data from proper motion.

The simple hypothesis[24] that the novae in spirals represent the running down of ordinary galactic stars by the rapidly moving nebulosity becomes a possibility on this basis of distance, for the brighter spirals are within the edges of the galactic system. Further, it is possible to explain the peculiar distribution of spirals and their systematic recession by supposing them repelled in some manner from the galactic system, which appears to move as a whole through a nebular field of indefinite extent.[25] But the possibility of these hypotheses is of course not proposed as competent evidence against the "island universe" theory.

CONCLUSIONS.

Observation and discussion of the radial velocities, internal motions, and distribution of spiral nebulae, of the real and apparent brightness of novae, of the maximum luminosity of galactic and cluster stars, and finally of the dimensions of our own galactic system, all seem definitely to oppose the "island universe" hypothesis of the spiral nebulae. Data relating to proper motion are also in better harmony with the hypothesis that spiral nebulae are not stellar systems. The evidence now supporting the "island universe" interpretation appears unconvincing, for many of the best arguments formerly proposed on that side of the question have been invalidated or much weakened by recent research. We have, however, no evidence that somewhere in space there are not other galaxies; we can only conclude that the most distant sidereal organizations now recognized—globular clusters, Magellanic clouds, spiral nebulae—cannot successfully maintain their claims to galactic structure and dimensions.

THE USE OF SELENIUM CELLS IN ASTRONOMY.

By Lewis J. Boss.

Selenium is a non-metallic element, occupying the intermediate space between Sulphur and Tellurium. It was discovered in 1817 by Berzelius while he was experimenting with the Falun pyrites, with a view towards producing sulphuric acid from them. Selenium is obtained in three different forms, namely, amorphous, vitreous, and colloidal selenium. There is also another modification of selenium, known as metallic selenium. Of these we need only be concerned with the vitreous and metallic forms.

The metallic form of selenium is produced from the vitreous generally, and is the only modification of the element which is light sensitive. The vitreous selenium is gradually heated until the temperature approaches 100°C. and then begins to pass rapidly into the metallic state, the temperature rising at 217°C.

This metallic selenium conducts electricity and exposure to light increases its conductivity. This effect is most pronounced when selenium is used which has been exposed for a considerable time to a temperature of 210°C., until it has attained a granular crystalline structure.

This final annealing is very essential to making the most sensitive and delicate cells. The selenium must be as pure as possible, as Marc has observed that impure selenium does not crystallize as well in a given time as does pure selenium. As a matter of interest it might be well to note here that in selenium crystals an X-ray analysis shows the selenium atoms to be placed at the corners of triangles in such a manner as to form hexagons. The distance between these atomic centers is 3.69×10^{-8} cm. when measured perpendicular to a regular surface running parallel to the principal axis. These hexagonal plates are fitted one against the other lengthwise, so as to build up an acicular hexagonal crystal. The distance between these as shown by the X-ray spectrum seems to be 3.7×10^{-8} cm., or .37 millionths of a centimeter.

After this crystalline state has been attained by the selenium cell it becomes very sensitive to even the most minute changes and variations in the amount of light allowed to fall upon it. Grupenberg has produced cells which recorded changes of one-hundredth candle power at a distance of a mile. As Marc has calculated the thickness of the selenium layer which is affected by the light action to be about 1/1,500,000 inch thick, it can be readily seen that small variations in light intensity will greatly affect the conductivity of the cell. This change also takes place almost instantly, at least the lapse of time is less than .01 second. There does not seem to be any appreciable difference in the action of the cell whether the light striping it is colored or not, although no one has studied this phase of the subject to any great extent. Personally I have thought that on some cells at least, certain wave-lengths of light, notably λ 680-660 (between the B and C lines of the spectrum) affected them to a greater extent than did other portions of the spectrum.

The field of variable star observations seems to open up a vast field for the use of these cells in that they will detect the smallest changes in light variations where the eye could see no change whatever. Many stars, such as α Orionis whose period has never been determined, offer a field of great interest to observers who may elect to make use of these cells. By means of a suitable indicating device a continuous curve of light variations may be traced throughout the night.

These cells may be used in determining the relative amount of light given off by an eclipsed body and, if calibrated beforehand, could be made to read in direct light units. During lunar total eclipses they might be used to measure the amount of earth-light received by the moon.

Another use to which they might well be put is the comparison of magnitudes and brilliancy of stars. For instance let the cell be arranged to receive the light from star A (let us say); then after noting on the indicating device (galvanometer, etc.) the deflection produced by the light of star A, swing the cell so that it receives the light from star B. If the deflection is the same, then star A and star B are of the same magnitude, but if the readings differ, then the proportion of difference in the readings is the proportion of difference in the magnitude. In this same way the cells might advantageously be used in recording brilliancy changes in Novae.

In view of the great delicacy and sensitivity of these cells it is to be hoped that they will become the subject of more research in the future than they have in the past, and that they may aid in the advancement of man's most sublime the magnitude. In this same way the cells might advanta- science—Astronomy.—Reprinted from *Popular Astronomy*, March, 1920.

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[23]Provisionally, let us say, of the order of 20,000 light-years. If novae in spirals attain apparent magnitude 16, certainly bright stars, if present, should be easily photographed, and the failure to resolve the brightest spirals indicates that they are not composed of typical stars. (*Cf.* a suggestion on the origin and constitution of spiral nebulae, *Mt. Wilson Contr.*, No. 161, p. 29, and also the mathematical theory by Jeans, *Monthly Notices* **77**, 186, 1917). At a distance of 20,000 light-years, if there were ordinary stars of absolute magnitudes between 0 and + 5, they would appear of magnitudes 14 to 19, and therefore conspicuous on ordinary photographs. Even if 200,000 light-years distant, the giant stars would be easily resolved on existing photographs.

[24]*Pub. Ast. Soc. Pac.*, **30**, 53, 1919.

[25]*Mt. Wilson Contr.*, No. 161, Sections VII and VIII, 1918.

The Fear of Being Buried Alive

Infallible Signs of Death

IN former times there was a very widespread fear among all classes of society of "burial alive" while in a comatose condition or what was generally known as a trance. Many people took elaborate precautions to prevent such a catastrophe, the fear of which was exaggerated by gruesome tales concerning open coffins wherein the corpses were found to have turned upon one side as if writhing in a vain attempt to escape the hideous death of suffocation, or where if placed in vaults they had gnawed their own fingers to the bone in the piteous effort to keep from starving and with a lingering hope that help might come before it was too late. Some persons went so far as to have coffins with plates of glass set in them, to have graves prepared with air shafts and to have tombs provided with various kinds of signalling apparatus. In 1824, Hufelend had a mausoleum built in Weimar, in which the biers were so arranged as to be connected with an alarm by means of threads fastened to the fingers and toes of the corpses, and a similar building was erected ten years later in Leipzig.

Readers of Edgar Allen Poe will recall that one of his most thrilling and hair raising tales deals with the case of a man who was possessed by such a fear of living interment, and had similar precautionary devices in his own home. Being obliged to take a journey, however, he awoke suddenly one night to the dreadful consciousness that his worst fears had been realized. The dank smell of earth was in his nostrils, he was apparently clad only in a shroud, and when with mounting horror he tried to rise, his head came in contact with a smooth board only a foot or two above him. He felt that the worst had happened! He must have gone into a trance and been hastily buried by the hands of strangers only to wake to face a hideous death by the torture of suffocation or hunger. Happily, returning memory reminded him in a few moments that he had taken passage upon a Potomac river boat the night before and was at present clad in his usual night garments and reposing in a narrow lower bunk upon a vessel which happened to be carrying a load of earth.

Many are the romances based upon the phenomenon of the simulated death of a living person, the tragedy of Romeo and Juliet being perhaps the most famous of all. Such cases abound also in both medieval and ancient European literature, in Eastern collections of tales such as the Arabian Nights, and finally in the folk-lore of many lands—as witness the charming story retold by Grimm of the Seven Dwarfs and their vigil over what seemed the lifeless but incorruptible body of the gentle maiden whom a jealous step-mother had tried to kill with a poisoned comb.

Some animals endeavor to escape their enemies by assuming a rigid and lifeless appearance when threatened, remaining perfectly motionless, even when touched or handled. The opossum is the creature most celebrated for this trick of "playing dead," but various other animals and insects exhibit it.

Strangest of all in this connection is the practice among the devotees of certain Eastern cults, notably in India, of inducing a condition of simulated death by means of fasting, prayer, intensive meditation, and other acts of self-hypnosis. It is even claimed by some of them that while in this state the body may be actually buried in the earth for many days. During this period of what may be called vital quiescence the soul is supposed to be able to leave the body and range at will in other spheres, returning finally enriched by rare spiritual experience. Even Christian annals contain many accounts of supposed journeys to heaven or to hell on the part of the soul while the body lay locked in death-like trance.

Many of the remarkable visions described by persons emerging from such a suspension of physical activities and sensations were undoubtedly related with absolute sincerity, and not infrequently the subsequent conduct of the individual was governed by ideas entering the mind during the supposed absence of the soul from the body. Here we trend upon the still more or less mysterious domain of the "sub-conscious mind." It would in fact be extremely interesting to examine some of these well-authenticated accounts of "unearthly visions" in the light of modern methods of psycho-analysis. But this would lead us too far afield for the purposes of the present paper, whose chief object is the statement of certain infallible signs and tests of death.

Since many people still suffer from such forebodings, though the fear of being buried alive is by no means so widely prevalent as formerly, it is of interest to know what are the true and unmistakable signs of actual death. The subject is interestingly treated in *Kosmos* (Stuttgart) of February 15, 1920. The writer remarks that by the expression "apparent death" we understand a condition in which a person presents the appearance of a corpse though still actually alive. It may be remarked that the better knowledge one has of the actual signs of death the less likely he is to be deceived by a simulated death. Children and wild animals may take a person lying in a faint to be dead, whereas an adult will at once know by his breathing that he is still alive. In the same way every zoologist knows that a fish or a frog can be frozen absolutely stiff and yet be alive, although not giving the slightest outward sign of life; indeed such a frozen animal can actually be cut to pieces without giving any evidence of sensation. At the present time it is extremely rare for a mistake to be made in this matter, because of more general education as well as of the greater skill of physicians than in earlier days. In the great majority of cases death comes with the implacable certainty of natural law. In such fevers as frequently end in death, such as scarlet fever, typhus fever, diphtheria, pneumonia, influenza, peritonitis, and inflammation of the membranes of the brain, or in blood poisoning, the dying person who has previously had a high flush and has been breathing rapidly and has had a rapid heart beat becomes pale and cold while his pulse beat disappears, his breath becomes weak and irregular and he finally gives the "death rattle," which is a characteristic sign of the approach of death. The possibility of any simulation of death is entirely excluded from this typical coming of the end in a demise due to a fever.

In a second class of deaths, which is very frequent, the end comes from the exhaustion of the patient. After weeks or months of illness, the latter, who has wasted away till he is little more than a skeleton, becomes so weak that he is unable to move or to take nourishment. Such deaths occur in chronic tuberculosis, cancer, old age, and the more serious forms of nervous and mental maladies. In this class likewise the possibility of mistake is absent. In a third class after the suffering of "a stroke" there was formerly considerable opportunity for error. For example, a man drops suddenly to the ground while talking, while at work, or while crossing a street and breathes his last in a few minutes. This manner of death befalls persons on the far side of fifty whose blood vessels have become brittle, or children whose heart has been injured by the toxin of diphtheria, or convalescents who have apparently recovered from an attack of the grippe, typhus, etc. In exceptional cases, too, sudden death is due to child-birth or to a surgical operation. In such cases a mistake as to actual death is possible, indeed, but extremely rare. The manner of death of such a person, who suddenly grows pallid, whose respiration falls and whose heart beats irregularly with a fluttering pulse, is so characteristic and typical that anyone who has observed it, even a few times,

can run no risk of making a mistake as to whether the victim is actually dead or not. The conditions which occasion the appearance of death in the living are found in only a small group of maladies. . . . including poisoning with morphine, chloroform, veronal, alcohol, coffee, nicotine; shock due to accident, a heat stroke or sunstroke, suffocation; certain rare forms of fainting, and finally, certain forms, likewise rare, of mental and nervous diseases, e.g. the severest form of hysteria. In all these conditions, and, as already said, exclusively in these and even then only very rarely, the patient sometimes exhibits the appearance of actual death while still living. He lies motionless for hours, he is cold to the touch, and his pulse, respiration, and heart beat may all be so very faint as to be imperceptible under a superficial examination; furthermore, the skin over the entire body may be pallid or blue in color, the eyes fixed and staring and the lips perfectly blue. Then, too, the skin may fail to exhibit the ordinary reflex action even when pierced with a needle. As we have said such a state which is so extremely rare that many experienced physicians may have failed to observe it more than a few times in a lifetime, cannot be distinguished at first glance from genuine death.

It is true that in spite of countless investigations no invariable sign has thus far been discovered by which death can be absolutely predicted within the first few hours after the demise of such a victim. It is possible that a certain sign of death is present, but we know of no such sign which is necessarily present as an invariable indication of death. In 1873 the Marquis d'Ourche offered a prize for the discovery of an absolutely certain sign of death recognizable by laymen. But while there were 100 entries, the prize could be adjudged to no one. Van Hassell's words hold good today: "Death is best recognized by the total impression it makes upon us." The greater the lapse of time after a person's demise the more unmistakable the signs of death become and the surer the diagnosis can be of excluding any mistake.

Those signs of death which sooner or later make their appearance in every corpse and which are more or less evident, so that both physicians and laymen can be quite certain of the fact of death are as follows:

CHARACTERISTIC SIGNS OF DEATH

1. *Rigor.*—The state of rigidity known as the death rigor makes its appearance either immediately or within the first ten hours after death. It consists in a gradual stiffening of the muscles proceeding from the neck downwards. This stiffness gradually disappears in the same manner after the lapse of from ten to 18 hours. This rigor is an absolutely certain sign of death. It can be distinguished from the rigidity due to cold by the fact that only the muscles are stiff, the skin above them remaining slack, whereas where a body is frozen not only the skin is stiff but also those external organs which possess no muscles, such as the ear, the point of the nose, the breast, etc. It is distinguished from the rigidity due to cramp by the fact that the muscles remain in any position which they are forced to assume, whereas when the rigidity of the muscle is due to cramp, the muscle immediately resumes its former position when this is altered.

2. *Death Spots.*—A second trustworthy sign of death is the spots of a bluish red or purplish color which appear upon the skin, being most marked upon the deepest lying portions of the latter, namely, the points where it is in contact with the layer beneath it; these spots are due to the collection of blood in the subcutaneous tissues.

3. *Shrivelling of the eyes.*—The human eye is maintained in a state of considerable pressure by means of an ingenious mechanism and it, therefore, presents a full rounded, smooth, moist, and glistening aspect. When death occurs the blood pressure at once falls and with it the internal pressure of the eye; the eyeball consequently presents a shrivelled appearance.

4. *Opacity of the Cornea.*—Soon after the occurrence of death the cornea of the eye, which during life presents a mirror-like appearance becomes dull and opaque through the alteration in its cells. In consequence of this the bright, warm mirror-like aspect of the living eye is changed into the dull glassy, expressionless gaze of the dead.

5. *Corruption.*—Like all other living organisms the human body is subject to decay when once the vital principle has departed. This decay may be hastened by certain factors such as heat and moisture or may be retarded by others such as cold, dryness, or the use of certain natural or artificial preservatives.

6. *The Green Color of the Abdomen.*—After death the skin of the abdomen assumes a greenish tint caused by the contents of the intestines.

All of these are absolutely infallible signs of death, but all of them may either be absent or so faintly indicated as to be imperceptible in the first few hours after death. Yet it is frequently very important to determine immediately whether a supposed corpse is really dead or merely in a state of stupor, since in many cases a person in the latter condition might be saved if prompt remedial measures are taken, whereas otherwise he would shortly die. It is very valuable, therefore, to know some definite means of determining whether death is actual or apparent without waiting for the appearance of the signs described above. Such information is of peculiar importance and value in cases of public disaster such as eathquakes, fire, flood, shipwreck, explosions, tornadoes, bombardment, etc., where hundreds of persons may be really dead whereas hundreds or even thousands of others may be merely suffering from shock. We quote from the same writer three reliable tests in cases of supposed death.

TESTS FOR THE IMMEDIATE DETERMINATION OF DEATH

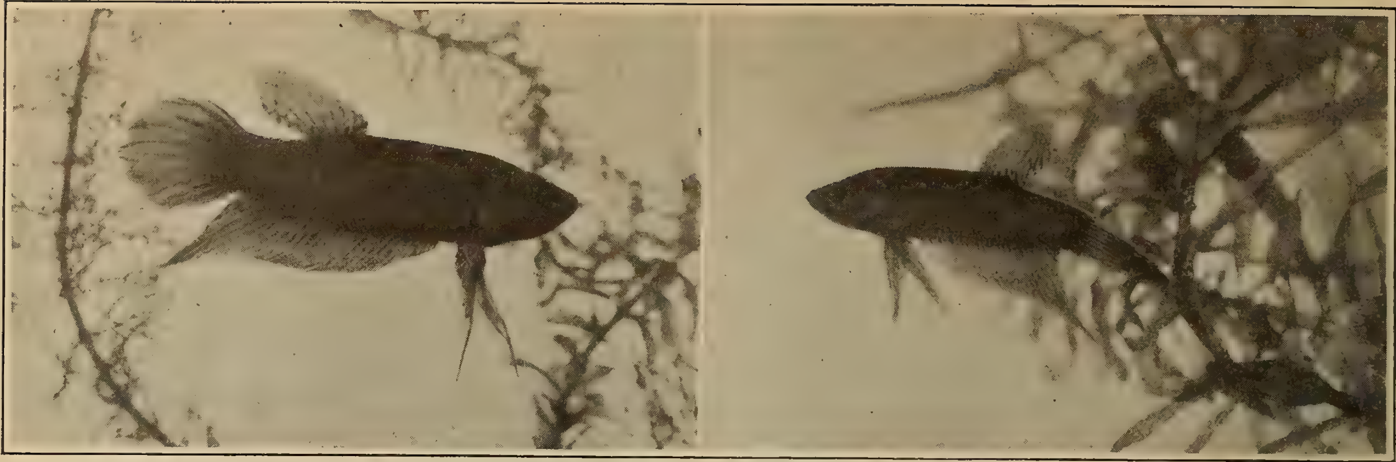
1. *Burning.*—If the skin be slightly burned by a match or bit of hot sealing wax it responds to the irritation when living by the formation of a blister filled with water, and it also has a reddish appearance. When the skin is dead, on the contrary, it forms no blister but separates like a bit of scorched leather, peeling off and showing a whitish color under the torn part.

2. *Finger tying.*—When a living finger has a piece of stout thread tied tightly about it so as to interfere with the circulation it swells through the collection of the blood which cannot follow its appointed course, and when the thread is cut the finger is marked with a white line which gradually turns red. This phenomenon does not occur when the finger of a corpse is tied.

3. *Electricity.*—If a person who is apparently dead though really living is subjected to an electric "shock," the muscles contract in the manner familiar to most people. About three hours after death even the strongest electric current fails to exert any effect upon the muscles.

Since the significant signs of death described above require as a usual thing several hours to make their appearance, the best safeguard against being buried alive is the law forbidding a corpse to be interred immediately after death.

In Berlin recently a nurse was discovered in an apparently lifeless condition and taken to a near-by sanitarium, where the physician declared her to be quite dead and had her body placed in another room. Fifteen hours later the supposed dead woman, however, exhibited signs of life. This case presents an obvious example of the wisdom of the law preventing too prompt interment. A hypothetical case is described as follows: Suppose a man was found lying in the woods seemingly dead from the effects of a large quantity of narcotic poison; suppose, furthermore, that since it was winter time his limbs were frozen stiff, so that the death rigor was apparently present. Suppose, too, that his skin was likewise cracked and altered in color and aspect by the frost so as to present the waxen pallor of a corpse. Suppose again that such a cold, discolored body was examined hastily by insufficient light at night. In such a case even an experienced physician might be deceived. And yet such a supposed corpse might really "come to life" many hours later when the effect of the narcotic from which he was suffering had worn off.



THE MOST BEAUTIFUL OF AQUARIUM FISHES: *BETTA SPLENDENS* (LEFT) AND ITS HANDSOME RED COUSIN *BETTA RUBRA* (RIGHT)

The Humming Bird of the Water

A Fish That Is a Devoted Paterfamilias

AMONG those fishes which are small enough to be suitable for an ordinary glass aquarium, one of the most interesting, as well as one of the handsomest is the *Betta Splendens*. The Betta is a genus of fishes belonging to the group of the *acanthopterygia* in the family of the *labyrinthidae*. All of these fishes have flattened bodies. The ventral fins are triangular and jugular, i.e. under the throat, and are composed of a few rays, the first of which are longer than the others. The pectoral fins are small; the candal fin is large and rounded, consisting of ten rays; the dorsal fin, which is situated nearly in the middle of the back, is short and spineless; the anal fin commences very far forward and ends close to the caudal fin; since the final rays of this fin are longer than the others the lateral line is interrupted. In general the shape and placing of the fin gives a peculiarly graceful appearance to the male fish. There is no swimming bladder.

Several species of the Betta are known including the *b.* trifasciata found in the rivers of the islands of the East Indian Archipelago, Sumatra, Banka, Billiton and characterized by three black bands running from the operculum (or gill cover) to the caudal fin; the fighting *Betta, b. pugnax* of the Malay Peninsula marked by black transverse bands and silvery longitudinal bands, besides two or three bands upon the head; the *bellicose Betta, B. bellicosa;* the red *Betta, b. rubra* and the "splendid" *Betta, b. splendens.* The latter two are dwarfed species not more than 5 or 6 cm. long and are particularly handsome.

All of these species are capable of living comfortably in small household aquariums provided the water in the latter be kept at a temperature of 25 or 26°C., which can easily be done by means of a small lamp. The *Betta Splendens* is especially remarkable for the dazzling beauty of its colors. When perfectly calm both sexes are yellowish brown banded with dark stripes, but when excited the fish undergo a remarkable change in color, form, and general aspect—the fins become bright colored, the back is curved and the gills swell up to such an extent that they extrude from the branchial cavities which contain them and are visible externally. The male exhibits an extraordinary brilliance of metallic tones and reflections; his back is reddish brown with iridescent gleamings while the abdomen and sides vary from red to green, to yellow, and to deep blue according to the way in which the light strikes them. Even the fins share these bright colors, so that the creature has been compared to a humming bird. The female is less vivid in color and her movements are slower and not so supple. These sudden changes of color are readily produced in the male when he catches sight of a rival. It is usual, where two males are kept in the same aquarium to separate them by a pane of glass.

One of the most curious habits of these fish is one which they share with the macropods of the same family, that of placing their eggs in a nest composed of bubbles of foam made by the male. This interesting procedure can be readily observed even in a small aquarium provided the latter be well furnished with plants, such as the *myriophyllae* rooted in sand and a few tufts of *riccia* (a cryptogamic plant similar to the marchenti or green moss); the floating tufts of the latter will serve as a foundation for the nest. If the aquarium is heated to the proper temperature the male will soon begin to take bubbles of air in his mouth and then eject them shooting them upward to a location where the plants are abundant and therefore suitable to retain them. He continues this until he has formed a layer of foam bubbles. These are remarkably persistent resembling glycerine bubbles because of the mucus secreted by the male with which they are mingled. From time to time the fish quits his labors to swim around about his mate, both displaying their most beautiful colors.

As soon as the nest is finished the female begins to lay her eggs, being assisted by the male, who curves himself into an arc of a circle in order to compress the body of his mate. About a dozen eggs are laid at a time, each one millimeter in diameter. These begin to fall slowly toward the bottom but during their descent they are caught by the male and carefully placed in the nest of foam bubbles. The entire deposit lasts two or three hours and from 300 to 500 eggs are produced.

The male now assumes entire charge of the nest, keeping the eggs in position and watching over their development. He is particularly careful to prevent the mother from approaching, probably from well founded fears of her unnatural liking for small fry. The eggs hatch at the end of 24 hours and the male keeps the fry in the nest for a few days until they grow strong enough to escape.

At this time they should be supplied with suitable food, consisting of infusoria, which will pullulate freely if a bit of cabbage stalk is placed upon the water. About 50 of the young fish can be obtained, two or three mm. in length. Their food should now consist of finely chopped earth worms or Daphnia. The most vigorous are ready to breed at the end of four or five months, but the most of them are not sufficiently mature until six or seven months old. They are very prolific, since a couple of weeks after the eggs have been deposited the pair can again be bred.

Parasitism and Symbiosis in Relation to Evolution

A Criticism of Prof. Portier's Theory of Universal Symbiosis

By Prof. Maurice Caullery, of the Sorbonne

Prof. Caullery is a distinguished member of the Faculty of Sciences of the Sorbonne, and is an eminent authority on the science of evolution. Both he and Prof. Portier have done valuable, original research work in biology and we are glad to give our readers the opportunity to compare their contrasting views with respect to the interesting subject of parasitism. The following paper delivered at the Sorbonne, Nov. 5, 1919, is the opening address of a series of lectures entitled "Evolution of Living Organisms."—EDITOR.

I WILL begin my subject by stating briefly the reasons for its choice.

Everyone is cognizant at the present time of the critical phase through which the transformist problem is now passing, a phase indicated by F. Le Dantes in 1909, in the title of one of his books: *The Crisis of Transformism.* This crisis, while a very real one, is undoubtedly merely a crisis of growth. For my part I do not seek to solve this problem, as does Le Dantes and I am ready to acknowledge that the great solutions in which more than one generation of naturalists have had entire faith, namely, Lamarckism and Darwinism, are today quite inadequate, at any rate, in their orthodox forms.

The study of all nature tends to impress upon our minds the conviction that living organisms have undergone a process of evolution and that they have passed through manifold stages before becoming the species whose fossil remains we find and those which are now living under our very eyes. But we do not yet know, it must be acknowledged, the nature of the essential factors in this evolution. All of the experiments hitherto made in the endeavor to furnish experimental proof of the possibility of transformation by natural selection or of the heredity of acquired characters have yielded but meagre results. And in the presence of these results the experimental study of heredity and of variation which have been pursued so actively and so fruitfully since the beginning of the 20th century, lead us provisorily at least, to conclusions which it is difficult to harmonize either with Darwinism or with Lamarckism. It is true that they themselves lead—at least when carried to extremes, to singular paradoxes, as was shown by W. Bateson, in 1914.[1] It is true, also, that what have seemed the best founded hypotheses in the world of science, such as that of universal gravitation or of the principles of electro-magnetism, have also finally encountered objections which have temporarily arrested our opinions with regard to them.

As regards living organisms the conformity of their structure to the conditions in which they live—their *adaptation* in a word, a fact of such general occurrence in nature and so impressively illustrated in the structure of living creatures, can no longer be explained with the beautiful simplicity of Lamarck's theory as being due to the direct action of the surrounding medium modeling the organism by means of its own activities. It seems rather more probable in fact that when the organism undergoes variations it reacts in a manner which is proper to itself and which is derived from its own constitution through the most varied factors which are capable of inciting it to action, and furthermore, that it passes either continuously or discontinuously through a series of forms which progress towards a definite end.

ORTHOGENESIS.

It is this idea which Eimer has tried to express by the word *orthogenesis* and this idea holds a place of prime importance in biology. Thus, one branch of the *Ondulidae*, starting from some ancestor analogous to the *Phaenacodus*, finally produced the horse, the *equidus* and in the same way the elephant type was gradually developed from the *Paleomastodon.* At the present time we have more and more numerous examples of series of this sort. The surrounding medium can have had at most merely an indirect action upon the development of these series . . . accelerating them, perhaps, or retarding them, or possibly exerting upon them a relative effect of elimination.

Under the influence of these data we have seen the reappearance even among those biologists who are rather strong partisans of evolution concepts similar to those which opposed Darwinism upon its origin. Thus D. Rosa has recently published under the title Hologenesis,[2] a theory in which he expresses upon the whole ideas similar to those of Naegeli, and in which he attributes evolution entirely to the interplay of the initial factors in the constitution of the organism.

HOLOGENESIS.

If adaptation is not necessarily a direct and normal effect of the action of the milieu upon the organism, we are led to conclude that it results secondarily from the choice by the latter of a mode of life suited to its previous constitution. This is what Cuénot has called *Pre-Adaptation.* The idea is by no means new; Darwin sought to ascertain how selection could have brought about the tongue of the wood-pecker, which is so marvellously adapted for the search for insects in the bark of trees. But Buffon, one of the forerunners of the transformationists, had already, in describing the behavior of these birds, come to the conclusion that "thus is the instinct of a bird bounded by a miserable and wretched life. He has received from nature organs and instruments appropriate to this destiny, or *rather he derives this destiny from the very organs with which he is born.*" Thus it is in the organ which creates the function instead of vice versa as in the aphorism of Lamarck.

Even if this explanation be fitting in certain cases, as might be suggested by modern experimental researches upon heredity, one would hesitate to assume its general application in view of the mass of adaptation arrangements which exist in nature and in view especially of the graduated series which they present. Would it be possible for a harmony so close and so thoroughly coördinated with the milieu to exist if the latter played no part in its accomplishment? Could a fact of such general occurrence possibly be due to a simple series of coincidences between the mileu on the one hand, and the constitution peculiar to the organism on the other, together with the laws necessary to their transformation? This is aside from a theological or creationist idea.

What still more gives us pause is, that under our very eyes we perceive that the reaction of the individual to the milieu is in a large measure adaptative; the transformation which a plant undergoes in passing from a lowland environment to a mountain environment, or vice versa, furnishes proof of this, but its adaptative modifications do not appear to be hereditary. Perhaps the solution of the difficulty lies in the general indications furnished by paleontology. The different types have not varied in a uniform and permanent fashion. Each one seems to have had its period of variability. During this period we may ask whether the hereditary variations were really independent of the milieu as we observe them to be to-day in organisms which are, perhaps, in a certain phase of stability, or is it true, on the contrary, that the individual adaptative reaction was hereditary.

[1] Presidential address delivered before the British Association for the Advancement of Science (The Australia meeting, 1914).

[2] D. Rosa, Ologenesi (Nuova Teoria dell Evoluzione, etc.) (Hologenesis—New Theory of Evolution, etc.). Florence, 1917.

However this may be the problem of the adaptation remains of prime importance. The phenomenon of parasitism affords an excellent domain in which to study this question, at the same time examining in this connection the question of variation in all its manifold aspects. Furthermore, there is a physiological as well as a morphological problem.

PREDATORYISM AND PARASITISM

From the physiological point of view, in fact, the phenomenon of parasitism presents a series of problems of the greatest possible interest as regards general biology.

To begin with it affords an excellent domain for the study of the reciprocal influence exerted by organisms. All organisms are separate entities and they are mutually engaged in the struggle for existence. The latter is a capital phenomenon, the investigation of which is one of Darwin's greatest titles to fame. But the bond between the parasite and its host is a definite one and the reciprocal action of the two antagonistic parties is definitely limited. But it is necessary here to define parasitism. A parasite is an organism which lives at the immediate expense of another organism, feeding upon the substance of the latter or utilizing the activity of the host's organs in order to obtain the substance of its own body and to accomplish its biological cycle. Except in the case of plants, which assimilate directly the carbon or the nitrogen of the atmosphere and the mineral substances of the earth, all living creatures nourish themselves at the expense of other organisms, and thus might be said to be parasites in a certain sense. But in ordinary conditions the animal kills and devours its prey; it destroys the latter in fact. This sort of life is called *predatoryism* and is properly distinguished from parasitism. The parasite feeds upon the organism at whose expense it lives without destroying it; it exploits the host to a certain degree in a methodical manner by turning aside to its own profit a part of the energy expended by the latter, thus occasioning more or less damage and exerting an action which is often more or less pathogenic in nature, but which is sometimes, on the contrary, perfectly tolerated.

One finds in nature a continuous sliding scale of stages intermediate between predatoryism and parasitism. Sometimes also two living creatures are associated together in a dependent relation, which constitutes to a certain degree an exploitation of one by the other, without there being, however, any direct borrowing by the second organism from the first.

COMMENSALISM

This phenomenon is known as *commensalism*, in other words, as the Latin origin implies, two organisms "eat at the same table." Thus for example, the *Nereilepas fucata*, a polychete, Annelid which is always found at the bottom of the shells of Gastropods (such as the Buccins) inhabited by the Pagures (*Pagurus bernhardus*) profits by the current of water which the Pagure creates in order to draw towards itself the prey upon which it feeds; some of the latter are thus turned aside from the Pagure to the Annelid. But the latter is not a parasite, it is merely a table companion, i.e., a *commensal.* It is difficult, therefore, to draw a definite line between commensalism and parasitism. Certain creatures, such as many of the Infusoria, like the Urceolaria, the Trichodins, and the Vorticellæ live in the homes of other animals of necessity; they are termed *Epizoa;* they are likewise commensals while at the same time borrowing directly from the animal which bears them the power of locomotion as well as very often the condition of aeration and of renewed water supply which are assured by the play of the gills of the host.

One of the characteristics of parasitism is the *fixed nature* and the *necessity* of the relations between the host and the parasite. A true parasite cannot fulfil its vital cycle without the aid of its host and lives at the expense of the latter. These associations are very precise in their nature, however, and are more or less intimate. But it is not always easy to say that in such an association one of the associates suffers at the hands of the other; there are certain very distinct cases in which it can be demonstrated that there is a physiological advantage, in, sometimes a *necessity* for, such an association on both sides. Thus these complexes of two organisms which mutually benefit each other and have a reciprocal intimacy constitute *symbiosis.*

SYMBIOTES.

In a recent book by M. P. Portier, *Les Symbiotes* (Prof. Portiers' views were described and discussed at some length in an article entitled Symbiosis, by May Tevis, which appeared in the *Scientific American Supplement* for November 15th, 1919), the author endeavors to establish the view that symbiosis is not only a phenomenon of general character but one of the fundamental bases of the life of a cellular organism. He regards the cell which is unanimously considered by modern biologists as the fundamental and indivisible organic unit, as being in truth a symbiotic association. In other words his idea is that the cell alone is incapable of existing without containing within it certain bacteria—true symbiotes —whose power of direct assimilation is employed for the benefit of the cell as well as for their own advantage, and M. Portier believes that he can recognize in the organites known to histologists as mitochondria, these symbiotic bacteria or bacteriods.

Autotrophs and Heterotrophs.—According to this author, therefore, living organisms are divided into two classes, namely autotrophs, i.e., bacteria, which are sufficient to themselves and heterotrophs, i.e., organisms having a cellular structure which assimilate their nourishment by the aid of autotrophs.

The capital importance of such a concept is at once evident. Its partisans declare that it will bring about a transformation of the primordial ideas of biology comparable in importance only to the revolution produced by the discoveries of Pasteur. But no matter how clearly expressed and how suggestive a theory may be, it is of value only in case it has been verified by the facts in the case . . . I do not hesitate to declare formally that up to the present time the author has not demonstrated anything convincing as to the justice of his hypothesis, and I believe that objections of fundamental importance may be proved in opposition to it. I make this statement unreservedly, but I am, of course, bound to prove the objections I advance.

OBJECTIONS TO THE THEORY OF UNIVERSAL SYMBIOSIS.

From the physiological point of view the study of parasitism includes a number of other problems. A parasite always lives upon a special sort of host and this specificity, which is always comparatively definite, is sometimes absolutely so. Thus the *Conospora longissima*, a gregarine studied by M. Mensil and myself[3], is constant and abundant in one of the forms of the *Dodecaceria concharum*, which we have designated by B; but it is never found in the A form, and yet this is the same species or, at any rate, a very closely related species of Annelid. Entomophagous (insect eating) Hymenoptera never deposit their eggs except in a denite species of insect. Girard believes, with apparent justice, that the general run of the species of the Epicarid Isopods are parasitic, each upon single species of Crustaceans, and that two similar parasites found upon related species belong to distinct species, even when the precise morphological difference in structure or in form is imperceptible.

The parasite Copepod which M. Mesnil and myself have just been studying[4] under the name of the *Xenocoeloma brumpti* is found only upon a single species of Polycirrus and not upon related species which are found near it. What is the mechanism of this specificity? In these cases, as among

[3]Caullery and Mesnil. Les Formes Epitoques et l'Evolution des Cirratulians (The Epitochal Forms and the Evolution of the Cirratulians) Ann. Univ. Lyon, Vol. XXXVIII, 1898.

[4]*Bull. Biol. de la France et de le Belgique.* Vol. LIII, 1919.

the insects, where the parasite actively penetrates the host, how does the parasite succeed in finding the proper host amid the immensity of nature, and how does it distinguish between related species? Is it through some form of tropism, by some olfactory sensation, for example, as is believed by J. Loeb? In the case of the passive ingestion of spores, as with the gregarine mentioned above, wherein the two forms of the host which live side by side, must certainly ingest the same sporocysts, why does the infection occur only in the B form? And this is closely related to another question, namely: How do the internal parasites, whether in the alimentary canal, in the deep lying organs, or in the colloma manage to exist within their host, maintaining immunity with respect to the humors of the latter's body, or to the phagocytes, whose function it is to digest or destroy the foreign substances or organisms which have made their way into the body? At this point the entire problem of immunity presents itself for our consideration.

And in what manner does the parasite exert an effect upon its host—an effect which is so definite in the case of certain organs. Thus in many instances the parasite produces, from a distance, alterations in the metabolism of its host, thus destroying the genital glands of the latter and producing *parasitic castration*. And after having produced the aforesaid effect, the parasite proceeds by way of good measure to occasion morphological modifications, particularly in the secondary sexual characters. It is a remarkable fact that the transformations thus produced by parasitism sometimes occur in groups such as the Arthropods, in which experimental castration, no matter at how early a stage has never been observed thus far to produce any alteration in these sexual characters. And yet the Sacculina, which more or less tardily infests the Crab, often profoundly modifies the secondary sexual characters of its abdomen and its abdominal claws. These facts, which were first pointed out by A. Girard, have been extended and strikingly illustrated by G. Smith.

In short, the list of important questions in physiology suggested by parasitism could be readily lengthened.

DEGRADATION DUE TO PARASITISM.

But let us return to problems of morphology and their connection with the more general problem of Evolution—as a matter of fact they are by no means independent of physiological problems. The reaction of parastism upon morphology is very striking. There is, in fact, no category of analogous facts in the realm of biology which affords the same breadth of vision. Parasites are distinguished from forms belonging to the same groups by traits so marked that the affinities of these parasites often become unrecognizable. Furthermore, there is an evident parallelism between the transformations which are produced in the various groups.

Parasitic *degradation* is a long established idea. The more profound the nature of the parastism, i.e., the more use the parasite makes of the host's activities to secure his own nutrition, the more the parasite becomes deformed and simplified. Thus, as a general thing the organs of locomotion and those of the senses tend to retrograde and even disappear. In some cases there is even no longer any trace of the original nervous system. The digestive organs become simplified, since the parasite, which absorbs only substances which are already fully elaborated and perfectly assimilable, needs not go to the trouble of making such transformations; there merely occurs a hypertrophy of some organs whose function it is to store up reserve material, such as the hepato-pancreas. The alimentary canal on the other hand, sometimes disappears completely, as among the Cestods, and the animal, immersed in assimilable nourishment, feeds itself by means of simple osmosis through its external tegument; the reproductive organs, in particular, are altered and are generally hypertophied, but in various manners. Sometimes the parasitism manifestly produces hermaphroditism. Sometimes, on the other hand, it exaggerates sexual bi-morphism, making of the female, stuffed with eggs, a giant upon which the dwarfed male lives as a sort of parasite. In one case as well as in the other the number of eggs produced by parasites is enormous—in this enormous production of eggs there is a compensation for the extreme mortality of those embryos and larvae which do not succeed soon enough in finding the indispensable host. This compensation is essentially adaptative and suggests theological illusions. Thus, parasites sometimes consist of little more than enormous egg sacks and the cycle of the parasite, starting from its meeting with the host is summed up in forming the substance of the eggs, laying them, and finally, incubating them until the hatching of the larvae.

There is, therefore, a very great simplification of the various apparatus which take no part in reproduction; there is a *degradation* if one choses so to express it, in comparison with free forms, but this term merely expresses a subjective point of view, and one might be equally justified in saying that parasites exhibit a specialization carried to a greater or less extent and upon the whole a peculiar adaptation which often attains a very great degree of perfection. In their own way these highly adapted forms might be regarded as being very highly organized. I will illustrate these ideas by a few examples and we shall observe, in particular, how a single group often exhibits successive stages of transformation connecting the forms ultimately attained with the normal forms although scarcely any perceptible resemblance between the former and the latter is apparent. Parasites, present together, more than any other category whatever of organisms a collective and striking illustration of adaptation. Nowhere else is the structure so clearly brought out as molded by the kind of life and nowhere else does pre-adaptation seem less probable.

Not only the adult has been thus influenced; the immature stages are no less so, and the requisite conditions in the finding of the host, which often involve a necessary passage by means of a provisory host (and consequently an enormous destruction of individuals in the process of development) are in correlation with the adaptative peculiarities of the larvae and frequently with the phenomenon of embryonic multiplication involving asexual reproduction. The comparison of various groups is, therefore, suggestive in this respect because we can thus observe parallel divergences with respect to normal embryogeny appearing in series which are entirely distinct, as if the action of the environment were effectively shaping in a direct manner the development and structure of the parasites, in a purely Lamarckian sense.

However, the problem is by no means so simple as it may appear. Conditions which are apparently similar sometimes bring about the most opposite results. A very striking example of this is found in the parasite Copepods. They attach themselves to their host after a period of free existence, during which they generally pass through the principal stages of larval development, like the free forms, attaining the stages which are known as syclopoid; they then attach themselves to the host and become deformed and degraded in the usual sense of the words. M. Mesnil and I have just finished the study of the truly astonishing retrogression of the genus which we have called *Xenocoeloma*, which actually succeeds in borrowing from its host, in the literal sense of the word, a portion of the latter's organs! It is impossible to imagine a more complete degradation and a more intensive parasitism. On the other hand let us consider another type of Copepods, the *Monstrillidae*. These peneterate the host as soon as they reach the Nauplius stage. They then lose all their appendages, forming a simple non-differentiated cellular mass which proceeds to develop within the circulatory system of an Annelid,[5] i.e., in conditions of supreme parasitism. One would expect a creature as degraded as possible from this mode of life. But this is by no means the case. From this parasitism, on the contrary, there issues a Copepod magnificently endowed for a free existence and provided with power-

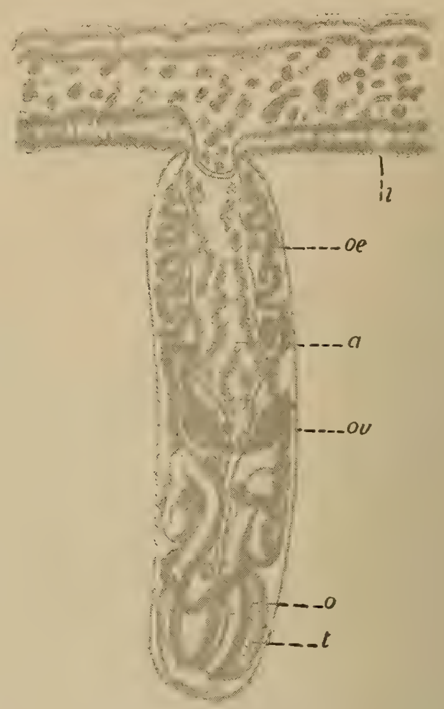
[5]A parasite species has been observed in a mollusc (*Odostomia*). Pelseneer, Bull. Biol. Vol. XLVII, 1913.

ful appendages for its pelagic life. A single feature of its organism, however, appears paradoxical, and was an enigma before the initial parasitic stages had been studied. The alimentary canal of these adult Monstrillidae is atrophied. We now explain this peculiarity by the fact that the animal accomplished its complete development in the form of a parasite, while its life in the adult stage is merely a brief pause at whose very beginning the sexual products are altogether mature and require only to be disseminated. The animal has no longer any need to assimilate nourishment. In the same manner the innumerable entomophagous insect included principally among the Hymenoptera and Diptera lay their eggs within the bodies of other species, where the eggs develop in the form of parasites producing free and perfect Imagos. In the same way also there is found among the Annelids a series of Eunicians which develop as internal parasites in other Annelids, ending in a free form in the adult state which is in no wise degraded by the parasitism. This shows that the mere fact of parasitism does not necessarily involve simple and uniform transformation.

Thus it is not evident that the striking adaptation of parasites is explicable any more than is the case with free forms by the simple Lamarckian mechanism as was formerly supposed. Here, too, parasites have been able to react according to the successive degrees of a vast orthogenesis. However, it is surely very remarkable to observe that parasitism produces in the most diverse groups parallel modifications which cannot possibly be completely independent of circumstances external to the organisms proper. When a Rhizocephalus crustacean exhibits the asexual modification demonstrated by F. A. Potts[6], is it possible to imagine that this result was an inevitable evolution resulting from the internal factors alone of these organisms independent of external circumstances? Can we refuse to believe that the progressive action of parasitism which, in the general evolution of types can be only a contingency, has been, at least, an external factor of considerable weight, and which has many times produced similar results under similar conditions, but in entirely independent series?

Doubtless free organisms present analogous problems, but parasitism is of peculiar character. The constitution of the fundamental types of the animal kingdom goes back into a practically inaccessible past. But the differentiation of parasites is a secondary evolution subsequent to the first. It is not reasonable to suppose that the parasites, with their intensive anatomical, embryological, and physiological deformations appeared originally in their present form. They are evidently derived from normal forms and nowhere have we stronger evidence of the truth of the theory of evolution . . . This secondary evolution is less remote than the original one, hence the study of parasitic forms is of peculiar interest with reference to the laws of evolution . . .

[6]Carnegie Institution, publication No. 215, 1915.



CROSS SECTION OF *XENOCOELOMA BRUMPTI* ATTACHED TO HOST. 14 DIAMETERS

i intestine of *Polycirrus* full of sand and forming slight hernia in the crustacean; *a*, axial cavity of *Xenocoeloma; ov*, ovary; *oe*, strings of ripening eggs; *o*, oveduct; *t*, testicle.

ANNELID WORM *POLYCIRRUS* HAVING TWO SPECIMENS OF THE *XENOCOELOMA BRUMPTI* ATTACHED TO OPPOSITE SIDES OF THE BODY AS PARASITES

. . . We have now arrived at a period in the history of the biological sciences when we are able to form a precise idea of the difficulties presented by their great problems. In the classic period of Darwinism it was generally believed that embryology would reveal all the secrets of morphology. To-day, we no longer hold this view . . . On the other hand, in the domain of physiology which is constituted by factors existing at the present time . . . the progress of all the experimental sciences daily proffers possibilities of new investigations. For example, cellular physiology is today in its prime and is making rapid progress. . . .

The tremendous researches which have been carried on since 1859, under the impulse of Darwin's book, have not enabled us to discover the essential solution of the transformist problem . . . But these researches have given us an incomparably greater knowledge of the forms of animals, of their intimate structure, and of the course of their development. It is thanks to this progress that we now perceive the inadequacy of certain solutions which seemed almost obvious in the years immediately following 1859. And the very difficulties offered by the problem of adaptation have proved that the science of morphology cannot be reduced to a few simple laws. Moreover, it is this progress which has enabled us to formulate the most vitally interesting questions in the realms of physiology . . . An infinite amount remains to be discovered in the domain of morphology and these discoveries may prove decisive for the direction of physiological researches . . . Even to-day we must profoundly admire the information given us by Claude Bernard in his celebrated work, "*Lessons Concerning the Phenomena of the Common Life of Animals and Plants*," with regard to the respective rôles of morphology and physiology . . . In our opinion future researches concerning parasitism show that the last word has by no means been said in morphology and in zoölogy.

THE PERFECT PARASITE.

In the foregoing article a reference is made to a parasite which has undergone such a remarkable degree of degradation as to have even borrowed some of its host's organs. This organism was described recently in an elaborate article by M. Caullery and Mesnil which appeared in the "Bulletin Biologique de la France et de la Belgique," Paris No. 2, 1919. This article is so very interesting and throws so much light on biological problems that we are glad to give a brief résumé of it which we quote from the Revue Scientific, Paris. —THE EDITOR.

IN the course of their researches concerning the Annelid worms of the Cape of the Hague MM. Caullery and Mesnil found upon a Polychete of the species *Polycirrus arenivorus* a small Copepod Crustacean[1] living as a parasite which at once attracted their attention, not only because of its extreme degree of degradation but also because of its peculiar relation to its host. They named it the *Xenocoeloma Brumpti*, the first word referring to the most remarkable peculiarity of the parasite, namely, that it has no individual alimentary canal. It exhibits an axial cavity which, as a matter of fact, does not really belong to itself, since it communicates with the coelomic cavity (i.e., the body cavity) of the Annelid, being in fact merely a diverticulum or blind pouch of the aforesaid coeloma of the Annelid, and being lined throughout its whole extent by the peritoneal endothelium of the host. However, the degradation due to the creature's state of parasitism by no means ends here.

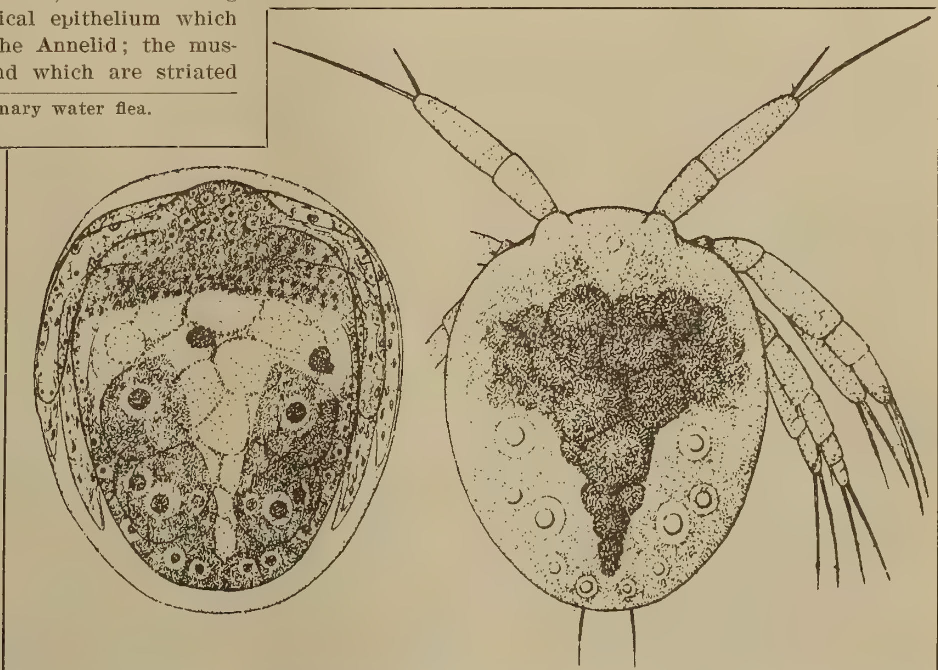
In aspect the *Xenocoeloma* resembles a small cylindrical rod a few millimeters in length attached to the body of the Annalid. It exhibits no sort of appendage, no special apparatus of attachment, and no prolongation or so-called "root" in the host. It possesses neither mouth nor anus, neither nervous system nor organs of sense, and not even any circulatory apparatus. More surprising still, just as it incorporates within its own body a portion of the coeloma of its host, in the same way it appropriates the latter's teguments, for the external covering of the parasite belongs in reality to the Polycirrus. Paradoxical as this may seem it is amply demonstrated by the numerous drawings and photographs made by MM. Caullery and Mesnil. It is an actual fact that the *Xenocoeloma* has no true tegument, its own having disappeared. The regular and cylindrical epithelium which covers the parasite really belongs to the Annelid; the muscular fibers which are found below and which are striated fibers, which are typical of the crustacean, belong to the parasite. The latter while extending outside the Annelid is still in reality an internal parasite. This shows us to what a remarkable degree the degradation has been carried. Of the original Copepod there remains practically nothing except the genital organs, which are extremely well developed; but other organs are either entirely atrophied or have become unrecognizable. The male animal seems to have completely disappeared while the female has become a hermaphrodite; the male portion of the genital apparatus has the appearance of being a superadded formation, a neoformation. The authors believe, though without distinctly affirming it, that the male genital organs have here been formed at the expense of a purely somatic tissue; if this fact is confirmed by later observation it will prove to be of great interest with respect to embryology. Upon issuing from the egg the larva is a Nauplius of typical aspect but having its various cellular areas heterochronous, i.e. same being retarded as regards the others. The morphological and physiological retrogression of the *Xenocoeloma* under the influence of parasitism recalls the most extreme examples of this phenomenon thus far discovered, such as the Cestods or the Rhizocephala. There is even, in spite of their differences, a certain analogy between these last and the *Xenocoeloma*. As the authors observe nutrition is accomplished in both cases at the expense of the host by a diffused absorption apparatus and beginning with products which are completely assimilated. In the case of the Sacculina the parasite accomplishes this object by penetrating with its roots all portions of its host's organism; but in the case of the Xenocoeloma it is the host itself within whose body cavity the entire body of the parasite is immersed.

[1]The Copepod Crustaceans include the ordinary water flea.

THE EFFECT OF PRESSURE UPON THE EYEBALL.

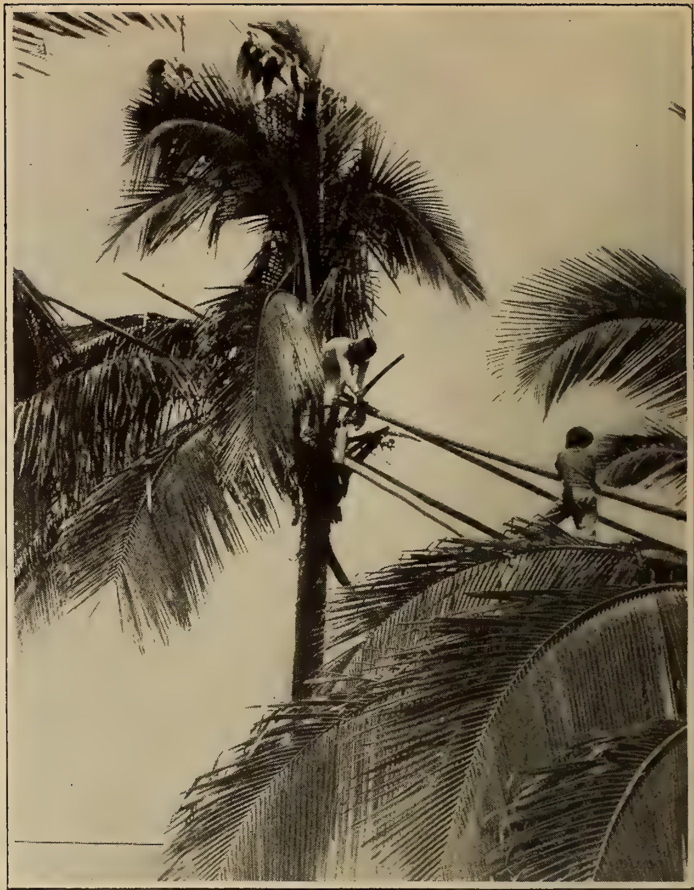
THE curious fact has been noted by a number of observers, including among others, the French investigators, MM. Achard and L. Binet, that ocular compression has as a result curious reflexes in other parts of the body, both in man and in animals (the rabbit and the dog). Such compression causes a marked modification in the functioning of the heart and other reflexes due to this cause affect the respiratory action, the blood vessels, and even the muscles.

TRANSVERSE SECTION OF YOUNG *XENOCOELOMA.* 155 DIAMETERS
a, axial cavity lined by peritoneal endothelium of the annelid; *tm, empty* maturation tubes of oöcytes immersed in a parenchyma intersected by muscles.



NAUPLIUS READY TO HATCH (LEFT) AND AFTER HATCHING (RIGHT). ENLARGEMENT 540 DIAMETERS
Observe the enormous lateral cells of the posterior region and the two nuclei of the vitelline mass. (Note that the term "Nauplius" is applied to a crustacean larva having three pairs of locomotive organs, a median eye and little or no segmentation of the body.)

GATHERING COCOANUTS IN THE PHILIPPINES



EXTRACTING SAP FROM THE COCOANUT PALM

Cutting the Cocoanut Cake

The Growth of the Tree and the Preparation of Its Products

By May Tevis

WHEN a commercial enterprise pays big dividends the process of dividing the shares is known in common parlance as "cutting a melon." If the commercial importance of the cocoanut trade continues to expand as it has done during the last few years, cocoanut groves will undoubtedly become so valuable that the sharing of profits from them may come to be known as "cutting the cocoanut cake." One of the greatest industrial geniuses of modern times, the famous multi-millionaire soap boiler, Sir William Lever, now Lord Leverhulme, of Port Sunlight fame, declared in the foreword of a book published shortly prior to the war, "I know of no field of tropical agriculture that is so promising at the present moment as cocoanut planting and *I do not think in the whole world there is a promise of so lucrative an investment of time and money as in this industry.*"

The very title of the book in which these enthusiastic words are found, "Cocoanuts: The Consols of the East," (1913) indicates his belief that such property is as valuable a security as British Government Bonds. Such an investment, in fact, might be said to be even better than government bonds since its value steadily increases for a number of years. The reader, who has thought of the cocoanut chiefly as an agreeable ingredient of cakes and confections will be curious to know the basis of so sweeping a statement—a statement which is agreed with moreover by various other authorities upon the subject. The answer is to be found in the enormous and steadily increasing value of cocoanut products.

PRODUCTS OF THE COCOANUT TREE: COCOS NUCIFERA

The chief of these products are copra, coir, cocoanut butter and toddy. But these are not all, since it has been computed that the cocoanut yields no less than 84 different products of value.

The cocoanut tree may be regarded, indeed, as one of man's most valuuable servitors, so that there is little wonder that some native tribes worship it as a symbol of divinity. This magic tree furnishes its happy owner with not only food, drink, and wine, but with oil, vinegar, light, timber for the making of houses and furniture, and fiber for the making of textiles, cordage and fish nets.

Before describing the preparation of the four chief commercial products we may cast a glance at some of the minor products. The nut itself is largely used by confectioners, restaurateurs, vegetarian specialists and others, not only in the popular dessicated form, but in numerous other ways.

The copra residue, after the oil has been expressed, yields a splendid food cake for cattle, sheep and poultry, being exceptionally rich in oil, albuminoids and digestible carbo-hydrates.

The shell serves many ornamental and domestic purposes, being used in the making of drinking bowls, beads, dagger handles, hookahs, ladles, water dippers, combs, fish hooks, spoons, rubber tapping cups, gourds, linoleum and other articels too numerous to mention. It also makes a superior charcoal, used in filling gas masks.

The dust of coir fiber is worked up to make felt for use under carpets.

The stem is utilized for furniture, fancy articles, sailing boats, rafters, laths, etc. Hollowed-out stems are used as channels, gutters, etc., and are largely employed in building operations among the natives. The wood is also susceptible of

a high polish and, under the name of porcupine wood, is imported into this country for use in cabinet making.

The bark yields a strong, cohesive gum.

The husk makes valuable manure, rich in potash and phospheric acid.

The leaves furnish excellent roofing material, mats, baskets, brooms, fodder for cattle, and manure. When burnt they produce an ash so rich in potash that it proves a good substitute for soap.

The nut, when young, supplies a delicious cooling drink and an attractive desert. It is also an ingredient for curry.

The green husk makes a toothsome preserve.

The young leaves are used for making a piquant pickle.

The early shoots of the seedling form a delicious vegetable.

Copra.—Copra is the trade-name given to the kernel of the cocoanut after it has been dried, when it is quite white, possesses a pleasant smell, and breaks with a sharp brittle fracture. The ideal article has been described as "that which yields a clear, white oil, free from fatty acid, pleasant and smooth to the taste, and having no pungent and acrid smell. The producers on the Malabar Coast, who have been established there for many years, have by dint of much devotion and energy succeeded in putting on the market an almost perfect product, even when prepared in bulk, almost wholly free from deleterious substances, which therefore rightly commands the keenest competition and the highest prices."

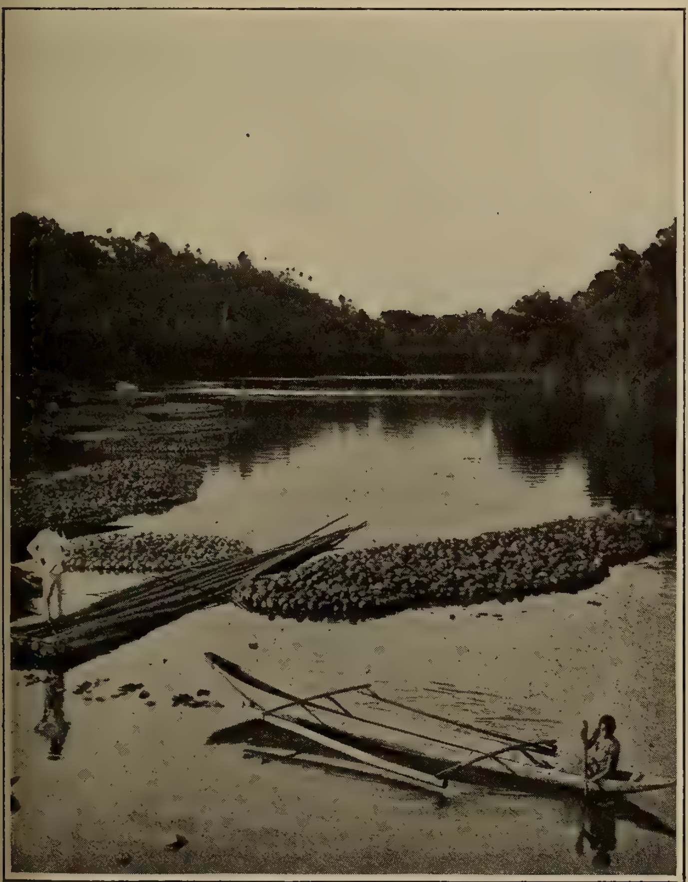
The process of drying the cocoanut is effected by one of four methods, which are: (1) In the sun; (2) in kilns; (3) in hot air chambers; (4) in rotary hot air appliances. The nuts are first husked and split open with a cutlass, and the milk is then poured out. The broken cocoanut is then divided into several pieces, from each of which the white kernel is extracted with a sharp knife, the pieces being spread out in trays, and, if the first process be adopted, exposed to the sun for a period of five to ten days, according to circumstances. In the old days the natives simply broke their cocoanuts in two and laid the halves on the ground on barbecues, or on drying racks and hurdles, with the kernel exposed to the sun. But trays are now in general use, and these are frequently attached to shelter houses, into which they can be transferred at night, or when rain threatens.

Although sun-drying produces a good-looking copra, it usually leaves behind it from 6 to 20 per cent of moisture, which influences the development of mould, a defect that seriously diminishes the market price of the product. This mould is ascribed by some authorities to the fact that fermentation can take place during the slow process of sun-drying. Experiments conducted by experts have established the fact that to obtain a copra free from any tendency to develop mould the moisture retained must not exceed 5 per cent. The impossibility of being able to depend upon a continuance of brilliant sunshine throughout the entire period of preparation renders sun-drying an uncertain, expensive, time-wasting process as compared with more scientific and up-to-date methods.

Generally speaking, in the Dutch East Indies the nut is gathered green and immediately cut into quarters by the natives by means of a sharp knife. Then it is exposed to the sun, on the beach or some other place, and it dries naturally, while retaining its white color. When dried the copra is placed in gunny bags for shipment. The work of drying, collecting and baling has long been almost entirely in the hands of the Japanese, who have demonstrated their superiority in this work.

At the drying stage women and children are employed to turn the copra and keep it well exposed to the sun. Living being cheap, consisting as it does mainly of fish and rice, the wages paid to these workers are extremely low.

Cocoanut Oil or Butter.—While copra can be used as a food and is so used by the natives, its great industrial value to the world is as a source of oil. For many years there has been a steady shrinkage throughout the world in the production of animal fats, whereas there has been a steady increase in population. This decrease in the available percentage of animal fats per capita was very marked even in the first 14 years of the present century. The Great War enormously increased this shortage of fats in three ways—the decrease



RAFTS OF COCOANUTS ON A PHILIPPINE RIVER

STRIPPING OFF THE HUSKS OF THE COCOANUTS

in production of oil bearing fruits and seeds, the increased consumption required in the feeding of armies since fats are an invaluable source of heat and nourishment for the human body, and finally, the enormous waste of fats involved in the manufacture of glycerine, the source of nitro-glycerine and other high explosives. At the present time the world is suffering from a fat famine, to which the present price of table butter bears melancholy witness even in the United States; but in the last few years cocoanut oil has come to be used upon a colossal scale in the manufacture of nut butter and other cooking fats, of soap, candles, cosmetics, glycerine, etc., as well as for lubricating and illuminating purposes. It is sometimes used also as a substitute for cod liver oil, being far more palatable than the latter, while likewise highly nutritious.

In former times cocoanut oil was extracted by very primitive native methods from the copra. Oil extraction is now, however, a factory rather than a plantation process. It involves two essential phases: First, the maceration of the copra, and second, the separation of the oil. The maceration is very perfect, consisting of grating or scraping and then of very thorough grinding. The oil is extracted by means of large and powerful hydraulic presses. In some cases there is first a cold pressure to produce oil of the best quantity, and afterward a pressure after treatment with hot water or steam; or the pulp may be squeezed both times after a preliminary heating to facilitate the removal of the oil. Oil expressed cold is as a rule of better quality, and oil destined for use as food is usually secured in this manner. After the oil is expressed it is permitted to separate by standing. The upper layers, usually cold enough to be sold in consistency, are then removed, and the residue is again treated to secure the remaining oil of poorer quality. The best mills in Europe sometimes succeed in extracting more than 70 per cent of oil from the copra used. This demands not merely very complete extraction but also that the copra used should have contained very little water. With most of the copra marketed it is impossible by the most perfect treatment to secure more than 65 to 67 per cent of oil.

Where the oil is required in a colorless condition, as for toilet and perfumery purposes, the Malabar system is to plunge the kernel into boiling water for a few minutes; it is then grated, subjected to pressure, and the pulp thus obtained reboiled until the oil rises to the surface.

Some Malabar experts pride themselves on their ability to produce oil so white that it is almost impossible to distinguish it from water when the two are placed in phials side by side. In the ordinary temperature of tropical countries the oil maintains a liquid form, but in lower temperatures, such as those common in this country and in Europe, it assumes a white butter-like solidity. Under conditions of extreme cold it can be separated into two distinct constituent elements, the more liquid of which is known as olein and the more cold as cocosin, or cocostearin, which is a somehat complex constituent containing fatty acids. When the oil is fress the flavor and odor are agreeable, and in that condition it is largely used in the East for food purposes and cooking. But there it rapidly becomes rancid, and when in that state is used for illuminating, soap-making, and other industrial purposes. Throughout the East kerosene is slowly superseding cocoanut oil as an illuminant, especially since mineral oil was discovered in Burmah and other Eastern regions.

The advantages claimed for nut butter prepared from cocoanut butter are its highly nutritious quality and the number of calories furnished the body, its freedom from pathogenic germs, the readiness of its digestion and the completeness of its assimilation by the body, besides, of course, the fact that it is much cheaper than cow's butter.

Oil Cake.—After the oil has been expressed from the copra, there is a residue which forms a valuable cattle food, or if not rquired for that purpose, makes an efficient fertilizer. In the East this residue is known as poonac, and the cake made from it possesses four valuable qualities, which are: First, the milk produced by poonac-fed cattle is of a better quality; secondly, the quantity is usually increased; thirdly, the resultant cream is firmer; and fourthly, the butter proportion is larger, and the color and flavor are improved.

Coir.—Coir is the commercial name of the fiber prepared from the husk of the cocoanut. The word is Malay or Indian in origin, but has been adopted into European languages. In countries where cocoanut culture is very old, the use of this fiber likewise dates further back than our knowledge reaches. In Polynesia and extending as far west as the Marianne and Caroline Islands, this is the main material used for cordage. It was in use as far west as Ceylon before the discovery of this part of the world by Europeans. In these parts of the world it served not merely for rope, and for string to make fish nets, or to tie the parts of houses together, but to calk boats, and in various other ways. For calking boats it is better than most other durable fibers because it will swell more when put into water, and will therefore make a tighter plug.

The chief peculiarity of coir rope is its elasticity. The cocoanut fiber will stretch fully 25 per cent without breaking. The amount which ropes made of it will stretch depends upon the method of manufacture, but in all cases they will stretch more than ropes made of any other of the commercial fibers. This makes coir rope especially desirable where it is subject to jerks. As used for fish nets, and in other ways which demand exposure to water, coir has the advantage that it is more durable than most other fibers; that is, it is less subject to decay.

The breaking strength of coir is 39 kg. when fresh and 24 kg. after having been immersed in water for 116 days, a length of time which causes the entire decay of both English and Indian hemp and of the American agave. The individual cells of coir are shorter than any other of the most important commercial fibers, including those of the ramie, of hemp, of flax, of abaca, of the American agave and of jute. Thus, the average length of the ramie fiber is 150 mm. whereas that of the coir is only 0.7 mm.

The strands which are extracted from the husks of the cocoanut and which are referred to in common speech as the fibers are 30 cm. more or less in length, depending of course on the size of the nut from which they are taken. The diameter is about 0.3 mm. In cross section, they are roundish or somewhat heart-shaped, the concavity or groove along one side being the place where the vessels were located. The strands are harsh and more or less dark in color according to the nuts from which they were secured and the method by which the fiber was extracted. The fiber is strongly lignified, and to this is due its color and harshness, and its relative brittleness as compared with pure cellulose fibers.

From what has been said as to the qualities of the coir, it follows that for ropes it is to be recommended where elasticity or resistance to decay are especially desired; but for general use it is an inferior cordage material because the brittleness of the strand makes it wear out more rapidly than many other kinds of rope, and because it is weaker than the best rope material. As a textile fiber it is of very little general value because of its coarseness, harshness, brittleness and color. The color can be removed, at least in very large part by chemical bleaching, but this treatment leaves it too weak for practical use. On the other hand, the qualities of harshness and stiffness and dark color all make it an especially good material for doormats and hallmats and for various kinds of brushes. It is for these uses that the coir has its chief market value. This combination of stiffness and elasticity also gives it a certain value as a stuffing fiber, and the poorer qualities of coir are marketed, under the name of mattress fiber, for such use.

It is also made to combine with wool in the manufacture of carpets and rugs of great durability and richness of effect, and to make brushes and brooms for household and stable purposes, matting for sheepfolds, pheasantries and

poultry yards; string for nurserymen and others for tying up trees and various garden purposes; nosebags for horses, mats and bags for seed crushers, oil presses, and candle manufacture. The refuse o fthe husks is used by horticulturists for many purposes.

A vast commerce is also conducted in the manufacture of coir cables, which are not only strong, elastic and buoyant, but are improved and strengthened by immersion in sea water, although fresh water is said to rot them. These cables are somewhat rough to handle, and not quite so neat looking as those made of hemp, but their greater elasticity renders them superior for many purposes.

Toddy.—In the East Indies palm sap used as a beverage is known as toddy. In the case of the cocoanut the sap is obtained from the unopened flower cluster. This is gradually bent downward so that when cut the sap will drip freely from the cut end. The tip of the cluster is then removed with a sharp knife, enough being cut off to include the ends of the younger branches of the panicle. The toddy collector carries a vessel usually of bamboo into which he pours the sap which has flowed from each cluster, leaving in its old place the vessel into which the sap has dropped. Each time the tree is visited another thin slice is removed from the cut surface and the thinner the slice the longer the toddy will continue to flow. If a slice is removed three times a day instead of only at morning and at night, a greater flow can be obtained for the 24 hours. The toddy is used either as a fresh beverage, or for the production of liquor, as well as for making sugar and vinegar, and as a source of yeast.

Arrack.—The strong liquor distilled from the sap of the cocoanut and other palms is known as arrack.

Sugar.—Cocoanut toddy has long been used as a source of sugar through out the Far East. The business, however, is everywhere a purely local one. The sugar content of the sap as it flows from the tree is high enough for the sap to be figured as a cheap source of cane sugar, but the fermentation is so rapid that the sugar which can be made from it is decidedly high-priced. For the manufacture of sugar, it is necessary to inhibit the fermentation of the sap as completely as possible. The commonest way of doing this in Malaya and Ceylon is to put into the vessels which collect the sap a little of some finely powdered bark which is rich in tannin. The sugar which is produced in this way is called "jaggery." From good sap, 1/12 the weight of jaggery can be produced.

THE GROWTH OF THE TREE.

As our pictures show, the cocoanut is a tall, handsome, and picturesque palm. While it is found in many parts of the tropics where it is able to obtain enough water, it yields the best results between the latitude 70°N and 12°S, which are outside the hurricane zone. Authorities differ as to whether its original home is in the islands of the Pacific Ocean or whether it is, like all other species of the genus to which it belongs, a native of tropical America. The nut thrives best where the mean temperature is from 75° to 85°F. and the mean annual rainfall is not below fifty inches. It derives special benefit by growing on the sea shore, as the palms require constant and adequate moisture, and soil that does not become sour and waterlogged, for their highest development. Mountainous districts are not favorable to the cocoanut, nor are localities with a torrid and dry temperature. Most experts agree that the best and most prolific estates are located near the sea, upon fairly level land, where rivers and torrents have brought down deposits of rich, friable loam. "The nearer the coast the better the nut" is the general dictum, although trees grow with fair success up to an altitude of 2,000 feet provided that the temperature requirements are fulfilled. But the cocoanut palm does not flourish on steep slopes nor in positions that are overshadowed and sheltered, and it cannot tolerate the presence of stagnant water in the neighborhood of its roots. Ample sunlight, a sufficiency of moisture and large quantities of salt in the soil constitute its essential requirements, and that is why it prospers on sea beaches or in places near the sea.

Obviously, soils vary according to region and location, but the best is an alluvial loam. Given this advantage the trees reach a state of great luxuriance. Light, deep, sandy loams overlying coral or some other porous substratum are also suitable, but the plant depends to a considerable extent on the fertility of the soil and requires a liberal supply of humus—i.e., decayed vegetable matter. Cocoanuts do not prosper on pure sand alone, unless it be repeatedly fortified by quantities of manure and humus. Heavy clay soils and all those with an an impermeable substratum which are likely to hold stagnant water, as well as all shallow soils, should be carefully avoided.

When the trees come into bearing the ripe nuts are usually gathered every two months by means of a knife attached to a pole. When the trees have reached a height of more than fifty feet however "cocoanut collectors" are employed. These pickers climb the trees until they reach the top where they are so near to the fruit that they can readily tell which is ripe and which is not. At the same time they are able to search for and destroy the beetles which attack the cocoanut tree. Very high trees can be climbed only when the weather is fairly dry since in the wet weather the trunks are too slippery. The coir substance, which clings to the stem must on no account be interfered with, since it assists in retaining the moisture around the bud.

It is better to let the nuts remain unhusked for two or three weeks after gathering, since this always insures a larger yield. It is estimated that 40 nuts per year can be counted on from each tree, though some give a much larger yield. The first transport of the cocoanut from the estate is frequently accomplished by binding them together into a sort of raft and floating them down canals to the sea.

COMMERCIAL IMPORTANCE OF COCOANUT PRODUCTS.

Not only has the shortage of fats become menacing to health and life in America thus ensuring, as we have said, a wide market in the Occident for cocoanut oil, but it is expected that a constantly expanding market for this product will be found among the 600,000,000 of the population in China. In "All About Cocoanuts," the interesting volume by Belfort and Hoyer a somewhat curious reason for this is given, to the effect that at the outbreak of the Russo-Japanese war oil producers in Europe and America made a sudden raid upon soya bean oil as a substitute for more expensive edible oils. This forced the Chinese to buy cocoanut oil as a substitute. But although soya oil receded in price the Chinese consumer has meantime become accustomed to the cocoanut oil and even prefers it.

The following figures represent the imports of cocoanut oil and copra for the fiscal years of August, 1913, to July, 1914, as compared with 1918-1919:

Cocoanut oil:	
August, 1913, to July, 1914........	74,067,372
August, 1918, to July, 1919........	345,737,913
Copra imports:	
August, 1913, to July, 1914........	100,853,374
August, 1918, to July, 1919........	296,599,419

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The author is specially indebted in the preparation of the present article to the two books which come first upon the present list:

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Chemical and Physical Properties of Dye-Stuffs*

Acid and Basic Dyes in Gelatin Solutions

By J. Traube and F. Koehler

[*The original article is both too long and somewhat too technical to be reproduced here in its entirety. It is of such great value, however, especially in view of the remarkable expansion of our dyeing industry that we are glad to publish an abstract of such portions of it as are of general interest.*—The Editor.]

In a previous number of this journal (1915, II, 42) we published an account of our researches concerning a large number of salts, acids, bases, narcotics, etc., with respect to the degree of rapidity with which a gelatine jelly at a given temperature (about 26°C.) passes over into the hydrosol conditions upon the addition of one of the said substances, as also the rapidity of formation of the gelatine jelly from the hydrosol condition in the presence of the acid substance. We found ourselves in agreement with the previous researches of Pauli, Schibig and others, to the effect that the dissolving of gelatine corresponds to a process of swelling while the formation of jelly corresponds to a process of shrinking. We found further that the laws determined for gelatine are applicable to other colloids such as albumen. This suggested that it would be of especial interest to extend these researches to the domain of dyestuffs. . . .

We are indebted to the "Badischen anilin-und Sodafabrik" for the following dyes, rhodamin B extra, night blue, rose aniline, eosin B extra, erythrosin G, pure red B conc., phloxin P, Bengal rose A.T., anthraquinon-green G.X.N., wool-violet S, methyl-green, crystal-violet, methylene-green BX, Toluidin-blue, methylene-blue, Nile-blue A conc., malachite-green BX, indigo-carmine.

From L. Casella & Company we received new-blue R, cyanol-pure-green G, water-blue, acid-green extra, tannin-heliotrope, cyanol-green 6G, formyl-violet SB, brilliant walk-blue, indazin N, acid-violet BS, naphtindon BB, isamine-blue 6B, tetra-cyanol SF, diamond phosphine R, cyanol FF, trypan-red and patent-blue V.

From C. A. F. Kahlbaum we obtained safranin G extra, Bismarck-brown extra, neutral-red extra, quinolin-yellow, martius-yellow, picrin-acid, gentian-violet BR, heliotrope BB, pure brown G, Congo-red, orange I, napthol-green B, azo-blue, azo-ruby S, Bordeaux R, naphtol-yellow S, thionin-blue, methyl-orange, brilliant-Congo G, light-green S, diamine-blue 3B, guinea-green B, Victoria-blue B, and rhodamin B.

Finally, we obtained from still other sources benzo-purpurin B and alizarin-saphiol, chrysaniline S, and chrysoidin S.

It is only too well known that in the case of many of these dyestuffs one must take into account certain impurities and adulterations.

The Rapidity of Solution and of Formation of a Gelatine Jelly.

We made use here of the same simple method employed in our previous work: 6 ccm. of a 0.1 per cent dyestuff solution was mixed with 4 ccm. of 6 per cent perfectly pure and neutrally reacting Nelson's gelatine which had shortly before been heated to about 50°C., regeant glasses of equal width being employed. After a certain lapse of time the glasses containing the congealed gelatine were placed in a thermostat (usually at 26°C.) and the melting of the gelatine was determined by means of small balls made of solid glass (these being better than beads). In the control solutions water was added in place of the dyestuff solution. The direct error of observation could not have been greater as a general thing than from one-half minute to one minute; however, in jellies of almost complete opacity, which were illuminated with an arc light, the error may be somewhat greater.

Since it was observed that the time required for solution of the jelly apart from the substance added depended primarily upon the length of time it took the jelly to form, the solution-periods for pure gelatine and for various dye-stuff gelatines were first determined. . . . The jellies were kept in an ice box. [*Table omitted.*] The first observation made was that the well-known continuous alteration (lasting for weeks) of a gelatine jelly, which can be perceived by the lessening of the vapor pressure, etc., corresponding to a shrinking process . . . and since such a hysteresis is not confined to gelatine alone this gradual process of shrinking is of much significance with respect to manifold biological and technical questions concerning the most various colloids, problems for example concerning dyeing and tanning processes, the period of incubation, etc.

It was further observed that the highly colloidal basic dyestuff, night blue (which contains dextrin) has a strong shrinking effect while the weakly basic rhodamin B behaves not much unlike water. Among the acid dyestuffs anthraquinon, like benzo-purpurin, has a strongly swelling effect while Bengal rose which like night blue does not permeate plant tissues—after a lapse of three days—has a shrinking effect. . . .

We next allowed the gelatine solutions which had served for the experiments to congeal once more and after a lapse of twenty-four hours placed them again in the thermostat at 26°C. and noted the time required for solution. [*Table omitted.*]

Later, the gelatines were again placed in the thermostat (after a lapse of another twenty-four hours) after previously being congealed in a freezing mixture at —10°C. and the solution time again noted. [*Table omitted.*]

It was found that after several days dye-stuff jellies, such as the gelatines of anthraquinon benzo-purpurin in which the dye-stuffs have a swelling action gradually undergo liquefaction starting from the surface even at ordinary temperatures or in the ice box, while in the case of dye-stuffs which exert a shrinking action, such as Bengal rose, night blue, etc., a similar liquefaction was not observed even after eight days. This phenomenon which was discovered to be quite general among the various dyestuff jellies examined is partly, but not entirely, dependent upon the collecting of bacteria and bacterial toxins.

It must be noted that the above mentioned dye-stuff-gelatine hydrosols, also can be refrigerated at —100°C. into solid carbon dioxide plus ether. The subsequent melting at 26°C. revealed, however, only very slight differences in the solution times compared to hydrosols which had been congealed at 0°C. . . .

Since the differences in the degree of shrinking and swelling of the dye-stuff jellies increase in proportion with the duration of the time during which the jelly is kept before the solution test, the following experiments were all carried out in such a manner that the jelly had previously been kept seventy-two hours in the ice box. The degree of concentration of the jellies was the same as above and the temperature in the thermostat was 26°C. to 26.5°C. Several days later (four to eight days) the experiment was repeated at a temperature of about 28°C. [*Here follow the series of figures obtained which are omitted.*]

The most noteworthy result of our experiments as shown in the tables is the demonstration that basic dyestuffs exert a shrinking action while acid dye-stuffs, on the other hand, exert chiefly a swelling effect, though a lesser portion of them

*Translated for the *Scientific American Monthly* from the *Internationale Zeitschrift fuer Physikalisch-Chemische Biologie* (Berlin).

also have a shrinking effect. The acid dye-stuffs which exert a shrinking action (Bengal rose, erythrosin, phloxin, pure red, pure brown, azo blue, etc.) belong as we shall see to the impermeable or slightly permeable dye-stuffs. It is these whose jellies do not deliquesce in the air.

It is a well-known fact that the non-crystallized basic dye-stuffs sometimes contain admixtures of dextrin, etc., while the acid dye-stuffs contain sodium sulphate, sodium bisulphate, etc. Since, however, only 0.06 per cent of the dye-stuff was contained in the jelly, the small quantities of such salts present are practically without influence upon the swelling; other experiments proved that even 0.5 per cent of dextrin had no influence upon the swelling. . . .

In the shrinking and swelling action exerted by colloids on the part of dye-stuffs we believe we have discovered a new factor which sheds light upon the most various phenomena not only in the technology of dyeing and tanning but in histology and possibly in photography, since what has here been proved true with regard to gelatine is likewise applicable to numerous other colloids, albumen, the fibers of plants and animals, etc., as shown by our experiments.

The greater the shrinking effect exerted by a dye-stuff the less necessary is it in general to assist the fixation by the employment of a special mordant. [*The accompanying tables are here omitted.*]

As shown by the tables basic dye-stuff may be expected as a usual thing to accelerate the formation of the jelly while most acid dye-stuffs retard the formation.

THE CAPACITY FOR DIFFUSION IN JELLIES AND ITS RAPIDITY; ALSO SWELLING AND SHRINKING IN RELATION TO CELL PERMEABILITY.

In a comprehensive study concerning the absorption of colloids by the vegetable "plasma-skin" Ruhland arrives at the conclusion that the capacity for diffusion and the rapidity of diffusion of dye-stuff solutions in jellies, especially in gelatine jelly, run parallel "without exception" to the capacity of dye-stuffs to penetrate living plant cells; also that "the living cell resembles an ultra-filter operating at a high pressure by reason of its semi-permeable plasma-skin with respect to colloids," and likewise that "the dispersive power of the jellies of the plasma-skin constitutes the decisive moment for the capacity and rapidity of absorption."

Ruhland's views are highly esteemed and justly so, and we should probably have never thought of criticising them but for the circumstance that the facts proved by us with regard to the capacity for shrinking of the basic dye-stuffs and the capacity for swelling of numerous acid dye-stuffs have forced upon us the conclusion that the capacity for swelling and for shrinking and therewith the capacity likewise of jellies to liquefy, or to congeal, as well as to lessen or to increase the friction of the cell sap, must be one of the factors which exerts an influence upon the permeability, and especially too upon the "storage" and rapidity of storage of dye-stuffs.

[*We are obliged here to omit the detailed criticism made by the authors concerning Ruhland's methods and conclusions together with the elaborate tables which accompany it, merely giving their final conclusions.*—Editor.]

When we compare the permeabilities determined by Ruhland (which must be determined for basic dye-stuffs in other plant objects as well as for acid dye-stuffs) with the diffusion values obtained by me, we undoubtedly perceive that they largely coincide. In spite of this it is not possible to regard the penetration of plant cells by dye-stuffs merely as a diffusion in jelly—in other words as an ultra-filtration.

Among the basic dye-stuffs we will refer only to rhodamin B and Bismarck brown; it is well known that in many dye-stuffs the differences of diffusion are very great where gradations of permeability are not specified.

With respect to acid dye-stuffs we found very marked exceptions in the case of wool-violet and Martius-yellow. We may mention, also, methyl-orange and fast-brown G which diffuse readily but permeate with considerable difficulty. Eosin and phloxin and also erythrosin and Bengal-rose diffuse better than might be expected from their very low degree of permeability. Acid green, light-green S, and naphtol-green permeate readily and diffuse poorly.

The very circumstance that we found very different permeability values for basic and acid dye-stuffs (though making use of similar sections of plants) whereas the figures for the jelly diffusion of acid and basic dye-stuffs exhibit similar intervals, indicates that there are concerned impermeability influences other than jelly diffusion alone. We know that salt ions such as potassium, ammonium, etc., penetrate cells with comparative ease because of the fact that they have swelling properties (just as narcotics do); but we also know, on the other hand, that shrinking ions such as calcium, SO_4, or non-conductors such as varieties of sugar penetrate only with great difficulty. When we find, therefore, that basic dye-stuffs nearly always have a shrinking action, while on the other hand acid dye-stuffs mostly, or at least very frequently (and in increasing measure with the lapse of time) exert a swelling action, we can hardly avoid the conclusion that we have here the key to the different behavior of basic and acid dye-stuffs with respect to capacity for storage and rapidity of storage, and furthermore, that the properties of swelling and shrinking cannot be excluded from the problem of permeability. . . . We are of opinion that when dye-stuffs such as eosin, phloxin, erythrosin, and Bengal rose permeate less readily than they diffuse in jellies, it is necessary to take into consideration the shrinking properties of these dye-stuffs (these properties being greatest in the poorly permeating dye-stuff Bengal-rose).

JELLY DIFFUSION AND DIALYSIS.

[*This section begins with a table here omitted, giving the rapidities of jelly diffusion and dialysis as noted by various observers.*—Editor.]

An examination of the foregoing table justifies us in concluding that *the rapidity of gelatine diffusion is parallel in general to rapidity of dialysis.* Only in the case of neutral-red is there a slight difference. Furthermore, the dialysis values . . . are much less exact than the values of the jelly diffusion and are derived moreover, from various observers. According to Hoeber, guinea-green B dialyses rapidly, while according to our own observation guinea-green R diffuses very slightly in gelatine. The value concerned is 4(2).

According to Teague and Buxton dye-stuffs are arranged with respect to the capacity for diffusion in one per cent agar almost in the same sequence as in respect to their capacity for dialysis through a cellulose filter. Eosin, methylene blue, chrysoidin, and safranin diffuse strongly, Congo-red and azure-blue diffuse very slightly, and night-blue not at all.

While we by no means claim that the rapidity of diffusion and that of dialysis run parallel to each other without exception, the coincidence of values shown above leads us to conclude that the permeability of plant cells may be regarded quite as justifiably as a simple dialytic process, as it can be considered as a process of jelly filtration. We do not deny, indeed, the possibility that jelly filtration occurs in plants, but convincing proof thereof is thus far not at hand.

The analogy of the results given by gelatine, agar, and cellulose, justifies us in believing that for different colloids the same or nearly the same sequence of diffusing and dialyzing substances exists.

THE COLLOIDAL CONDITION OF DYE-STUFFS.

Ruhland has justly observed that the direct ultra-microscopic examination of dye-stuffs has laid bare many contradictions. Since dye-stuffs are frequently impure, containing small admixtures of sodium-sulphate, dextrin, etc., which influence the ultra-microscopic image, such contradictory results are not to be wondered at. In spite of this we are of opinion that more precise ultra-microscopic investigations are best adapted to furnish a concept of the colloidal condition of various dye-stuff substances.

Ruhland believes that certain indirect methods, like the

method first proposed by Hoeber of the precipitability of acid dye-stuff solution by varying concentrations of calcium chloride or nickel-chloride, as likewise the jelly diffusion methods of Bechold (utilizing the principle of ultra-filtration) are to be preferred, although these methods are certainly far from perfect.

Pelet-Jolivet correctly points out that the methods of precipitation are primarily related to a chemical exchange. The sodium salt of the dye-stuff is exchanged at least partially with the calcium salt or nickel salt concerned, whose difficult solubility will primarily influence the process. In spite of this we are also of the opinion that in general, or at any rate usually, the values obtained by this method admit of the conclusion as to the dispersive power, but the method should be controlled by the direct ultra-microscopic method.

The same restrictions must be applied to the principle of ultra-filtration.

If this principle be strictly accepted the measurements of diffusion would yield an exact measure of the dispersive power and if we admit further that the rapidity of diffusion and permeability always run parallel, we shall arrive at the theory advocated by Ruhland according to which the magnitude of the colloid particles is decisive with respect to the permeability. But this is really a revival of the old "sieve theory" of M. Traube—at any rate so far as colloids are concerned.

Attention must be called, however,—in opposition to the principle of ultra-filtration—to the alterability of the dispersing jelly through the substance added. If we filter through gelatine various dispersed particles of the same colloid or different colloids having the same degree of swelling or shrinking effect, we are justified in determining in this manner the relative magnitude of the particles, but if we try to compare dye-stuffs having a marked swelling effect with those having a marked shrinking effect, we shall inevitably arrive at false conclusions concerning the degrees of dispersive power. Thus for example, a dye-stuff of the eosin group may be only slightly colloidal, and yet in consequence of its capacity for shrinking it may take the place of a highly colloidal condition. In spite of these restrictions, however, which must be considered in estimating the value of the ultra-filtration method, we are of opinion that it is usually possible to obtain in this manner an approximately correct idea of the dispersive power of the dye-stuff colloid. However, Ruhland's "sieve theory" should be restricted in this case also by saying that the diffusion and permeability are influenced, not only by the magnitude of the particles but also by the capacity for swelling or shrinking of the dispersoid with respect to the dispersion medium.

MOLECULAR WEIGHT, COLLOIDAL CONDITION AND DIFFUSION, ETC.

In a work by Traube and Onodera it was shown that in aqueous solutions of free alkaloids sub-microns do not become visible until the molecular weight exceeds a certain minimum magnitude. Thus there is indicated a dependence of the colloidal condition upon the molecular weight; however it is pointed out that the molecular weight is not the only factor in question, but that constitutional influences are present, though, perhaps, of secondary character. It was not known at that time to one of us—namely Traube—that similar views had already been proposed with respect to dye-stuffs. Krafft has pointed out the significance of the molecular weight with respect to the colloidal properties of dye-stuffs. Buxton and Teague have shown furthermore that the capacity for dialysis and therewith the dispersive power, in spite of certain deviations, bear a quite unmistakable relation to the molecular weight; Wo. Ostwald has published in his volume of Colloidal Chemistry a table in which the same results are indicated.

[*Here follows a table which we omit showing the degree of parallelism between molecular weights and colloidal condition.* —Editor.]

To begin with we would like to call special attention to the fact that the jelly diffusion can by no means be regarded always as a measure of the dispersive power. We may also remark that the high molecular weight of the group: Eosin, phloxin, erythrosin, and Bengal rose, can be traced to the greater number of atoms of chlorine, bromine, or iodine; furthermore, the nature of the atom doubtless plays a part. With the exception of these dye-stuffs, however, it cannot be doubted that in general the capacity to form colloidal aggregates—as in the alkaloids—increases in proportion with the molecular weight, even though other influences cannot be excluded. This relationship between molecular weight and dispersive power is of the highest importance with respect to the principles of colloidal chemistry. . . .

CONCERNING STORAGE AND DYEING.

. . . The rapidity of storage is an exceedingly important factor. We will now enquire what factors are chiefly operative in causing a dye-stuff to be precipitated at a definite *locus* of the cells.

The reason that the basic dye-stuffs have a considerably greater capacity for storage than the majority of the acid dye-stuffs, is to be attributed above all to their property of producing a shrinking effect. The greater the shrinking effect exerted by the substance the less will be its need of a mordant in order to fix it. Dye-stuffs which have a swelling effect exhibit a tendency to permeate while those which have a shrinking effect have a tendency, on the contrary, to allow themselves to be absorbed. A dye-stuff having a strong shrinking effect, such as night-blue or naphtindon, naturally exhibits this tendency in a far greater degree than a slightly shrinking dye-stuff of great dispersive power, like methylene-blue, etc. Krafft has already pointed out that it is also true for highly colloidal acid dye-stuffs, like azo-blue and diaminpure blue that they are capable of dyeing cotton without a mordant.

In our diffusion experiments in which 5 ccm. of 10 per cent gelatine were placed in small test tubes and covered with 1 ccm. of a 0.1 per cent solution of dye-stuffs, we found that after a lapse of eight days a complete clarification of the dye-stuff solution occurred in the aqueous superficial solution of azo-blue, isamin-blue, naphtindon, and new-blue, with a deposit of the dye-stuff upon the surface of the gelatine. We are here concerned with highly colloidal dye-stuffs which, like azo-blue, isamin-blue, and naphtindon, undergo no diffusion in the jelly, or which like new-blue diffuse very slightly.

An almost complete clarification with a dyeing of the gelatine surface was observed in the case of heliotrope, water-blue, fast-brown, Congo-red, fast-red, Nile-blue, Bordeaux, Victoria-blue, brilliant-Congo, and alizerin-saphiol. These are all highly colloidal dye-stuffs and the process of dyeing can be most clearly observed here. The more dispersive dye-stuffs, which diffuse more strongly in the gelatine do not exhibit this capacity for storage or else show it only in a slighter degree; furthermore it need scarcely be mentioned that in the absence of the gelatine phase even the highly colloidal dye-stuffs are not deposited. The gelatine surface exerts an attraction upon the particles of dye-stuff whether these be acid or basic, provided only the said particles are of sufficient magnitude. The particles become aggregated and form upon the surface of the jelly a cohesive layer of the dye-stuff of measurable thickness. But it must be emphasized that we are here concerned with a colloidal and not a chemical process, as is true in general of dyeing processes.

It is a known fact that the capacity for absorption of substances frequently bears a close relation to the activity of the surface. In the section following are contained the superficial activities of the dye-stuff solutions here investigated. It might be thought that a dye-stuff of great surface activity, e.g. rhodamin B would be absorbed in greater measure, in spite of its great dispersive power, than methylene-blue for instance; however, basicity also plays a part here and we lack technical information concerning the dyeing power of the various dye-stuffs as such, to enable us to express this relation between surface activity and storage capacity.

We are concerned naturally in the consideration of the dyeing capacity and storage capacity of dye-stuffs, not merely with the dye-stuff itself, but above all with the electric charge of the *locus* in which the storage takes place, with the presence of the substances which are found there, with the medium in which the dye-stuff operates, and particularly with the possible addition of a third substance to the medium involved.

We must, therefore, at once reject the hypothesis of those authorities who uphold the chemical theory of the process of dyeing according to which the fibers must contain basic or acid groups in order to absorb acid or basic dye-stuffs respecitvely. It is certainly true that when at the *loci* in question an-ionic colloids (like tannin) are found dye-stuff cations are there deposited and vice versa; but on the other hand the presence of free hydrogen ions at once accelerates the deposit of dye-stuff an-ions and on the other hand the presence of hydroxul ions accelerates that of dye-stuff cat-ions. It is well known in fact that it it customary in the technology of dyeing to add to the sodium salts of the acid dye-stuffs, assistant acids such as sulphuric acid, etc., or acid salts, while to basic dye-stuffs sodium carbonate, etc., are sometimes added.

[*We here omit a series of detailed experiments along this line, giving merely the definite conclusions of the authors.*—EDITOR.]

Taking everything into consideration we must again lay stress upon the fact that in our opinion the storage and dyeing process is colloidal in character and not stoichiometrical-chemical in spite of the partial decomposition of the dye-stuff salt. Definite influences are exerted by the nature of the dye-stuff, the respective acidity or alkalinity of the dye-stuff ion, the swelling or shrinking properties connected therewith, the dispersive power of the dye-stuff and apparently, also, the surface activity. A definite influence is exerted furthermore by the acid or basic reaction of the medium and the storage *locus* (limiting surface of the phase) as, likewise, the presence of colloids having opposite electric charges, which occasions a flocculent separation. All the influences which occasion a lessening of the dispersive power of the dye-stuff increase the absorptive power.

THE SURFACE TENSION OF DYE-STUFF SOLUTIONS.

[*We omit the lengthy table with which this section opens. It gives a list of basic and acid dye-stuffs with their surface tensions* (*determined by a stalagmometer*), *and in parallel columns the average duration of life of fish in a* 0.02 *per cent solution and of tadpoles in a* 0.1 *per cent solution.*—EDITOR.]

While the determination of the toxicities of dye-stuffs lies somewhat outside the scope of the present article we find it desirable to record the degree of toxicity with respect to both animals and plants of the various dye-stuffs examined. The results of the investigation of barley will appear shortly elsewhere; we give here only those respecting "Blitzfisch." Our investigations indicate that in basic dye-stuff solutions the surface activity is by no means a negligible factor. It is clearly connected with the complex magnitude which we term toxicity. The case is different with the acid dye-stuffs.

Two fishes each were placed in 0.02 per cent solutions of pricric acid, Martius yellow, Bengal-rose, Brilliant-walk-blue, erythrosin, tetra-cyanol, Congo-red, dioinin-blue, Guinea green, fast-brown, Bordeaux, acid-violet, methyl-orange, naphtol-yellow, acid-green, crystal poncean, quinolin-yellow, water-blue, and fast-red.

Picric acid and Martius-yellow proved very poisonous, killing the fish in 5 minutes. In fast-brown both were dead after 6 hours, and one was dead in brilliant walk-blue and in Bengal-rose each. Both were dead after 20 hours in tetra-cyanol and one each in crystal poncean and Congo-red. All the other fish were very lively.

Two fish each were then placed in 0.1 per cent solution (i.e. five times as strong) of the following dye-stuffs; cyanol, indigo-carmine, Orange I, naphthol green, light green, heliotrope, eosin, phloxin, azo-blue, azo-ruby, anthra-quinon-green, brilliant Congo, and thio-carmine. After 2 hours the fish in Orange I and in brilliant Congo were dead; those in phloxin still exhibited reflex motons. We conclude therefore that nearly all the acid dye-stuffs are quite non-poisonous, including those with great surface activity. . . .

SUMMARY.

1. Basic dye-stuffs in general exert a retarding action upon the rapidity of solution and an accelerating action on the rapidity of formation of a gelatine jelly. *Hence they have a shrinking effect.* As a usual thing the more colloidal the dye-stuff the greater the capacity for shrinking.

2. Acid dye-stuffs in many cases accelerate the rapidity of solution and retard that of the formation of a gelatine jelly. *Hence they have a swelling effect in many cases.* However there are many also which have a shrinking effect (Bengal rose, erythrosin, azure blue, etc.).

3. Diffusion tests in gelatine show that in general, but by no means always, the capacity for and rapidity of diffusion of dye-stuffs run parallel to the permeability in plant tissues, but that we are not justified in regarding permeability as a simple process of jelly diffusion—the less so, since it has been shown that the capacity for and rapidity of dialysis through paper filters, etc., likewise usually run parallel to the capacity for and rapidity of jelly diffusion and permeability.

4. In general the greater or lesser capacity for jelly diffusion, and therewith the principle of ultra-filtration, may be regarded as a measure of the magnitude of the colloid particles, but this is by no means always so, since shrinking and swelling substances constantly alter the medium.

5. As in the alkaloids, so also in the dye-stuffs the dispersive power is primarily dependent upon the molecular weight. The capacity of substances to form colloidal aggregates is accordingly chiefly a function of the molecular weight.

6. The capacity of dye-stuffs to exert a shrinking or swelling effect is a factor which must be taken into account in the most various problems of biology as well as in the theory and technology of dyeing. Swelling favors permeability as a general thing, while shrinking favors storage. The problem of permeability requires consideration of this new factor for its solution.

7. New views with respect to the question of dyeing in general are based upon experiments in gelatine diffusion; among other things the effect of the addition of acids to acid dye-stuffs and of alkalies to basic dye-stuffs may be made clear. A dyeing process is in general colloidal in nature and not a chemical process governed by stoichiometric relations.

8. Measurements of the surface activity of dye-stuff solutions and determinations of the degree of toxicity show that in the case of basic dye-stuffs there is a definite (though not exclusive) connection between surface activity and toxicity with respect to tadpoles and fish.

NEW METHODS OF PREVENTING THE PROPAGATION OF TYPHUS.

A NEW "de-lousing" method has been developed by the Pasteur Institute of Paris and applied at its various centers throughout France. Clothing, bedding, etc., which are to be treated are hung up in a large oven or chamber, heated to 45 degrees C. and containing 20 c.c. of chloropicrine per cubic meter of air (i.e. 1 to 50,000). Chloropicrine is well known as one of the asphyxiating gases used in the war. France possesses a considerable stock of this product, which like many others of its kind, can now be turned to a good advantage. Prof. G. Bertrand, of the Pasteur Institute, has recently examined the disinfectant and parasite-destroying properties of this substance. After a 20-minute treatment in this chamber, the parasites are entirely destroyed throughout the whole thickness of matresses and clothing, and the latter can be worn immediately afterwards without having suffered in the least. The present method, which is due to a careful research on the part of specialists, will render the greatest service against the propagation of typhus.

Commercial Fertilizer

Brief Discussion of Its Functions and Methods Used in Its Manufacture

By Thomas R. Harney

FOR years past, except for a period during the early part of the war there has been a steady increase in the amount of artificial or "commercial" fertilizer used in the United States, and now that we are preparing to get settled down after the turmoil, it is probable that this increase will continue. This is especially probable in view of the present difficulties with the quantity and quality of farm labor, and of the growing agitation for intensive farming, since it can be shown by agricultural experts that in many cases the judicious use of the proper artificial fertilizer will serve the double purpose of saving labor and of increasing crop yield. Since successful crop production, as a factor in the reduction of living costs, touches all of us, a brief discussion of the functions of commercial fertilizer and of its methods of manufacture may be of interest.

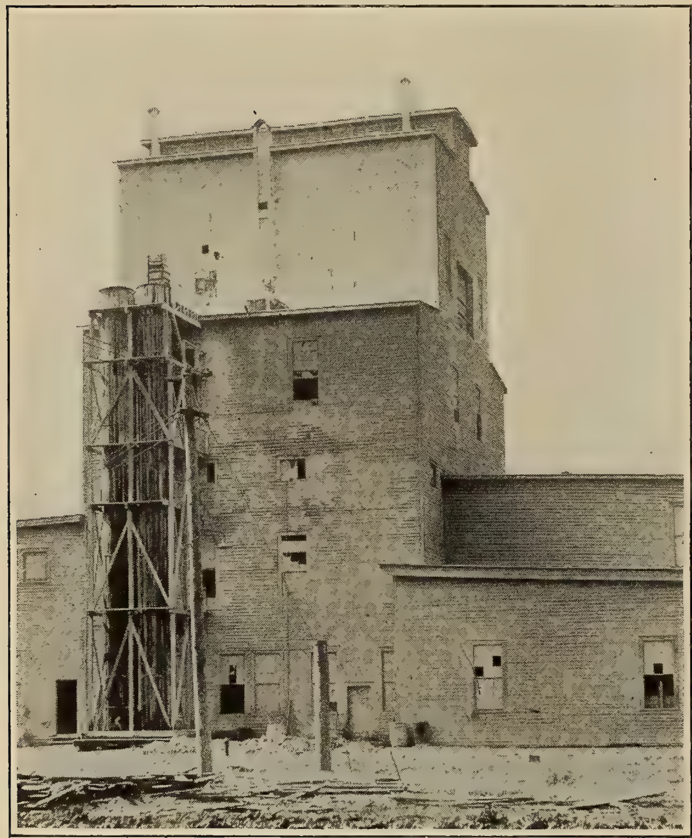


FIG. 1. ACIDULATING BUILDING WHERE ACID PHOSPHATE IS MADE

In the production of any crop there are three principal elements which the soil must supply, namely, nitrogen, potassium and phosphorous. Through long established custom, in the fertilizer business these elements are usually known as "ammonia," "potash," and "phosphoric acid," and for the purpose of being conventional I will so refer to them, though scientifically the names are incorrect, being the names of compounds containing the corresponding element, which compounds are seldom present to any large extent in fertilizer.

Certain soils, particularly those of virgin nature, may be sufficiently rich in all three elements; others, either naturally or through exhaustion by continued cultivation, may need the addition of one, two or perhaps, all three elements from some outside source. The office of commercial fertilizer is to aid the natural farmyard manures in supplying this lacking plant food, in the proper proportions for a given soil or a particular crop.

The nitrogen used in artificial fertilizers is supplied from various sources, some of them inorganic, as in the case of nitrate of soda and sulphate of ammonia, and some organic as tankage, dried blood, fish scrap, cottonseed meal, etc. Nitrate of soda is found in Chile, and in practically no other place in the world. Its preparation for use consists merely in "leaching" or dissolving in water to free it from insoluble impurities and in the subsequent evaporation of the water solution to produce the crystallized salt. Sulphate of ammonia is produced by absorbing in sulphuric acid the ammonia gas which is given off during the manufacture of coal gas in by-product coke ovens or gas producers. During the war the manufacture, or rather the recovery, of this material was considerably increased, due to the fact that a large part of the available nitrate of soda supply was required for the manufacture of nitric acid. I say the "recovery" was increased, for we have always produced many thousands of tons more than we have saved, allowing it to escape all over the country from the chimneys of our houses and our power plants, and from the vent-holes of our old-time "bee-hive" coke ovens. Sulphate of ammonia is only one of the by-products of the distillation of coal, for the loss of which future generations will jeer at us as a race of barbarians.

There is another source of ammonia, which has developed rapidly in the last few years, and which seems destined, perhaps, to play a very important part in the future. It is known as "cyanamid," and is the product obtained by what is, to date, probably the most successful of the "air-nitrogen" processes. The details of its manufacture would require too much space for this brief discussion, but it may be said in passing that by the aid of the electric current the producers of cyanamid have tapped what appears to be an inexhaustible source of nitrogen. Every ounce of that element which occurs in the cyanamid of commerce has come from the atmosphere, and as the atmosphere is nearly eighty per cent nitrogen, it remains only to bring the process to the highest possible state of efficiency to have at hand an ample supply of nitrogen for fertilizers—or explosives.

The other organic ammoniates are too numerous to permit of complete discussion here, but in most cases their names indicate the sources from which they are derived. During the last year or so the use of some of them as stock feeds has become so extensive as to make the current prices almost prohibitive so far as fertilizer manufacture is concerned.

The sources of potash in the United States are also too numerous to allow a discussion here of its preparation. The "American Fertilizer Handbook" for 1919 says: "Production of potash in the United States during 1918 came from seven different sources, as follows: Natural brines, alunite, dust from cement mills, molasses distillery waste, waste sugar refinery water, and wood ashes. The amount from other sources was negligible." Alunite is a potassium bearing mineral found in some of the western states, and kelp is a sea-weed. The other sources are self-explanatory. Of the potash producing capacity of the United States, fifty per cent is represented by the natural brines of Nebraska and twenty-eight per cent by other brine lakes. (The American Fertilizer Handbook, 1919.)

Since practically all commercial fertilizers contain acid phosphate as their source of phosphoric acid, the manufacture of this compound will be discussed at somewhat greater length.

RAW MATERIALS.

The raw materials necessary for the manufacture of acid phosphate are sulphuric acid and "phosphate rock." The

former is sometimes manufactured in a plant operated as a department of the fertilizer works, and sometimes bought and shipped in from the outside. In either case it is used in the form of a water solution, usually containing about sxity-five per cent, by weight, of sulphuric acid—the approximate strength of "chamber acid" direct from acid chambers. The phosphate rock is mined, in the United States, principally in Florida, Tennessee, and South Carolina, though there are large, undeveloped deposits in other states, especially in the west. It occurs in various forms, from the very hard "blue rock" of certain deposits in Tennessee, to the gravel and pebbles of Florida "land-" and "river-pebble." It is usually crushed, washed, and dried at the mines being delivered to the fertilizer plant, sometimes ready for the pulverizers, and sometimes requiring a preliminary rough crushing.

There is some difference of opinion as to the exact origin of the phosphorous in phosphate rock, but it is pretty generally agreed now that it was originally of an organic nature, such as animal remains, bones, excreta, etc. The chemical composition varies almost as much as the physical form, but most plants in the country operate on rock containing from sixty-five to seventy-five per cent of tri-calcium phosphate, or "bone phosphate of lime" as it is commonly called.

CHEMICAL BASIS OF MANUFACTURE.

The chemistry involved in the manufacture of phosphatic fertilizer is based upon the fact that there exists a series of compounds formed from phosphoric acid and lime, all of which contain these two substances in varying proportions, but which have very different characteristics otherwise. The two of these compounds which are of particular interest from a fertilizer standpoint are known technically as "tri-calcium-phosphate" and "mono-calcium acid phosphate," the former being the bone phosphate of lime mentioned above as occurring in phosphate rock, and the latter the "acid phosphate" of commerce.

The chemical formulae for these compounds are, respectively, $Ca_3P_2O_8$, and $CaH_4P_2O_8$. As their names indicate, the former contains three atoms of calcium (Ca), equivalent to three molecules of lime (CaO), to one molecule phosphoric anhydride (P_2O_5), while the latter has only one molecule of lime to one molecule of the anhydride, but in addition has four atoms of hydrogen. The presence of the hydrogen gives to the compound the title "acid" phosphate.

By the action of the proper amount of sulphuric acid tri-calcium phosphate may be converted into the mono-calcium compound, or to express it in a more scientific manner, four atoms of hydrogen are substituted for two atoms of calcium. The displaced calcium forms calcium sulphate ($CaSO_4$) with the sulphate (SO_4) group of the acid, and this calcium sulphate then plays an important part in the conditioning of the mass through the taking up of two molecules of water by each molecule of calcium sulphate, to form gypsum ($CaSO_4 2H_2O$), thus serving as a dryer.

Besides the differences in constitution shown above, mono-calcium acid phosphate has the important property of being readily soluble in water, which tri-calcium phosphate is not. In this fact lies the value of acid phosphate as a fertilizer, since when placed in the soil it becomes immediately available for plant food through the action of moisture. On the other hand, tri-calcium phosphate, or raw phosphate rock, while probably rendered ultimately available through the action of the dilute acids usually present in soils, would require considerable time, perhaps years, to furnish as much plant food as the same amount of phosphorous in the form of acid phosphate would provide in a few days or weeks.

THE PROCESS.

Fig. 2 is a flow sheet of the acid phosphate process, showing in outline the steps which are taken to convert raw phosphate rock into commercial fertilizer.

When the rock arrives at the plant, it is sometimes ready for the pulverizer, and sometimes requires a preliminary rough crushing. In case the crushing is necessary the usual apparatus is the familiar jaw crusher, so set as to produce material which will pass a one-inch ring. From the crusher, or from the cars, as the case may be, the rock is fed to the pulverizer shown in Fig. 4, where it is reduced to dust. In the past it has been customary to be satisfied if this dust be sufficiently fine for about 80 per cent of it to pass a 60-mesh screen (i.e., a screen having sixty meshes to the lineal inch, 3,600 to the square inch) but the modern tendency is to work toward a greater fineness. A good many of the later plants are using dust 90 to 95 per cent of which will pass a 100-mesh screen.

The pulverizer, or "mill" shown in the illustration depends solely upon centrifugal action for its grinding. As may be seen by an examination of the picture there is a central shaft, driven by a pinion and large ring gear. Attached to this shaft, inside the casing of the mill are three arms, forming a "spider," and at the end of each arm, suspended in trunnions, is a "roller." The main part of the roller is approximately two feet long, with the roll proper at the lower end,

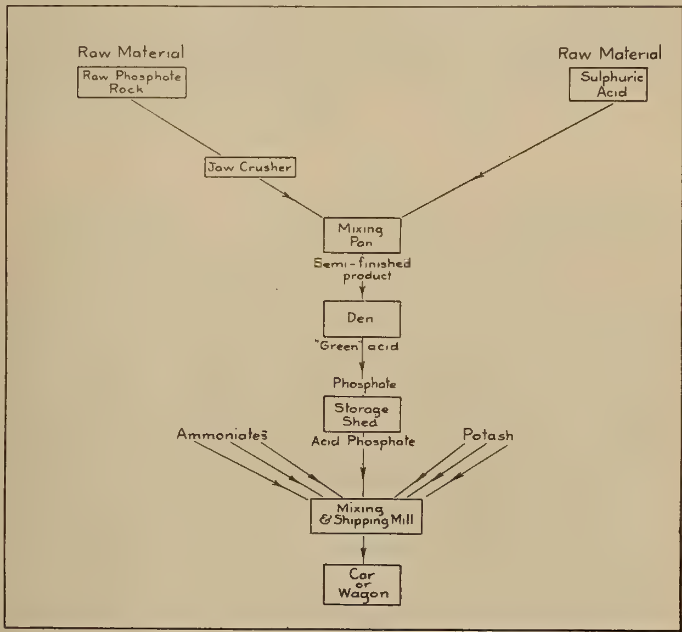


FIG. 2. STEPS IN THE PROCESS OF CONVERTING RAW PHOSPHATE ROCK INTO COMMERCIAL FERTILIZER

and as the shaft is revolved, the centrifugal force causes this roll to press against a "bull ring" on the inside of the mill. The rock is fed to the inner chamber of the mill by means of the spout shown at the right of the ring gear. This spout, at its upper end, leads to a rock bin to which the rock is raised by a bucket elevator.

Just back of the bull ring, and between it and the casing, is a fifty-mesh screen, and when the dust is sufficiently fine to pass this screen it drops through a chute into a screw conveyor operating under the mill, and is delivered to the boot of another bucket elevator which raises it to the top floor of the building. This elevator can be seen, faintly, at the extreme left of the picture.

Some pulverizing units have the screen and mill separate, the dust being elevated from the mill, screened and the oversize automatically returned to the mill for another grinding, and where the extreme fineness mentioned above is desired, air separation is used. This consists in raising the dust from the mill through pipes by means of a draft of air, and then suddenly allowing the air to expand in a "dust collector." This expansion, of course, lessens the velocity of the air current, and the coarser particles of dust are dropped while the finer and lighter particles pass on to the dust bin. The coarser material returns to the mill for another grinding.

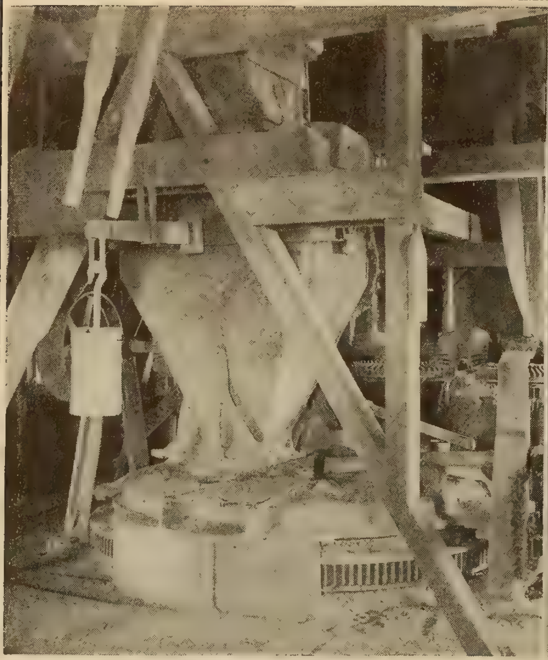


FIG. 3. MIXING THE DUST WITH SULPHURIC ACID

FIG. 4. THE PULVERIZING MACHINE WHICH REDUCES THE CRUSHED ROCK TO DUST

The next step in manufacture is the mixing of the dust with sulphuric acid. This is carried out in the "mixing pan" shown in Fig. 3. This is a shallow, cast iron pan, the stationary upper part of which can be seen in the illustration. The lower part extends beneath the floor. As may be seen a geared driving ring completely surrounds the body of the pan. This is driven by a pinion, concealed behind the stanchion at the extreme right of the figure, and in revolving rotates the pan. The object of course, is to give a thorough stirring to the contents, and this purpose is still further served by the "plows," the driving gear of which is shown. A shaft from the beveled ring gear, shown just behind the post at the right center of the illustration, extends downward through the stationary top of the pan, and ends in a four-armed spider. To each arm, and extended still further downward into the mass to be mixed, is a cast steel bar, chisel pointed, and with the point bent slightly forward in the direction of rotation of the spider. As this spider revolves, and the material in the pan is carried past by the rotation of the latter, this material is given a very thorough mixing. When it reaches the other side of the pan it meets another plow, hidden, in the illustration, behind the hopper, which revolves in the opposite direction from the first one, so that a very few rotations of the pan serve to complete the mixing process.

In the operation of "mixing," also known as "acidulation," the dust is drawn by gravity from the dust bin on the next floor, into the large weighing hopper, shown in the center of the illustration. This hopper is shown empty; when full the weight arm in the foreground rises in its slot. During this operation, an approximately equal weight of about sixty-five per cent sulphuric acid is being drawn into a measuring tank, not shown in the figure. When both are full, they are run into the pan simultaneously, the dust by opening the slide shown at the bottom of the hopper and the slide shown in the stationary top of the pan, and the acid by opening a valve in the lead pipe line which can be seen crossing over to the center of the pan, behind the stanchion at the right. It usually requires only about a minute after both materials

FIG. 5. THE TRACK UNDER THE DEN. THE GREEN PHOSPHATE FALLS THROUGH SLOTS IN THE FLOOR OF THE DEN INTO DUMPING CARS

are in the pan for the mixing to be complete. The operator watches the action through the dust charging hole, and when it is completed he raises a plug, the operating handle of which can be seen just over the acid inlet pipe, allowing the mixed mass to flow out through the bottom of the pan into what is known as the "hot den" or simply the "den."

This den is merely a strongly constructed room, capable of being tightly sealed except for one opening connected to a large exhauster which draws off the steam and gases generated by the action. The function of the den is to conserve the heat generated and to keep the reacting materials pressed together until the action is complete. This action, of course, commences as soon as the acid and dust come in contact in the pan, but it has been found to continue for some time after that.

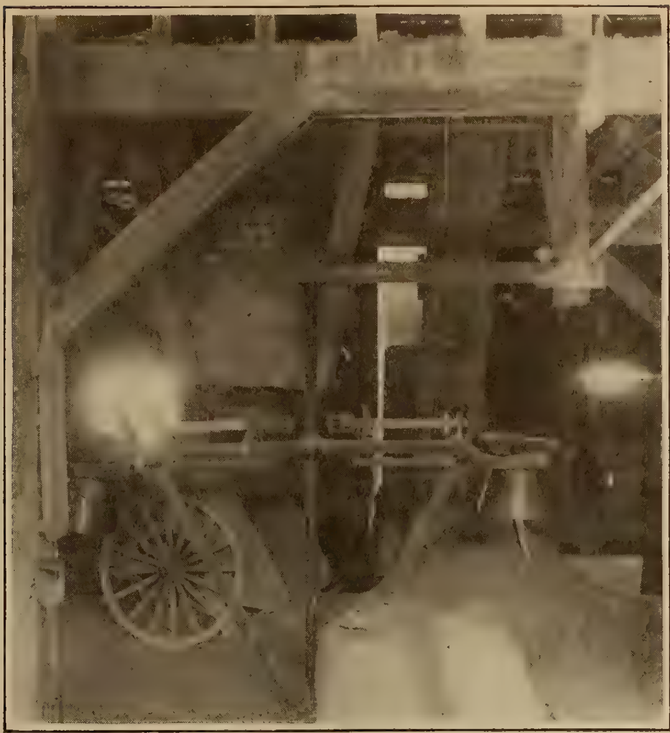


FIG. 6. THE MIXING PLANT

After from twelve to twenty-four hours in the den action has practically ceased, though it may go on slowly for several days or weeks, and the material, now "green" acid phosphate, is withdrawn. This withdrawing is accomplished in various ways—sometimes by conveyor, sometimes, in the very old plants, by hand, and in some of the most modern plants by having the den top removable, allowing the den to be emptied by an electric crane and bucket. In the particular plant shown in the illustrations, there are two slots in the bottom of the den, covered by loose boards while the den is being filled, but which can be opened when desired. The green phosphate is raked through these slots by hand and falls into dump cars operating on the track shown in Fig. 5. As can be seen these tracks extend over the storage piles, and the car when filled is drawn out over the pile by the cable shown at the left of the figure. This cable operates on the endless chain principle over a large motor-driven pulley, and when the car reaches the pile which is being built up, a trip block automatically opens it, allowing the contents to fall on the pile. As the car comes back the same trip block closes it, so that it is again ready to be filled as soon as in position. Until the introduction of the electric crane and bucket in the fertilizer business, this was probably the most efficient method of emptying the dens.

Fig. 7 is a view in the storage and shipping shed, and shows a pile of acid phosphate in storage. The length of time which this material remains in the shed depends somewhat upon the time of year at which it was manufactured—whether near to or far from the planting season. Most operators, however, prefer that it "cure" or dry for two or three weeks before any attempt is made to ship it, since before shipping or when mixing with ammoniates of potash-bearing materials, it must be put through a "disintegrator" or "clod-breaker" to break up the large clods shown at the foot of the pile in the illustration.

There are many methods of carrying out this shipping and mixing from the old hand methods of some of the smaller plants, to the highly efficient "batching" hoppers and automatic weighing machines of the large modern works. Where the acid phosphate is to be shipped out as such, without any added ammonia or potash, it is simply put through a disintegrator and broken up so that it will pass a three or four-mesh screen. It is then ready for shipment.

The method of mixing in the plant shown in the illustrations, which might, perhaps, be considered a good average of all methods, is as follows: Acid phosphate, one or more ammoniates, and one or more potash-bearing materials are weighed up in wheelbarrows, on small platform scales. The calculations of the amount of each material are a simple matter of arithmetic, the chemical analysis of each, and of the desired mixture being known. When weighed they are dumped into the

FIG. 7. THE STORAGE AND SHIPPING PLANT SHOWING PILES OF ACID PHOSPHATE IN STORAGE

boot of an elevator, the housing of which can be seen, with the sunlight falling on it, just back of the two bags in Fig. 6. The elevator raises it to a disintegrator at the top, and from there it goes over a three or four-mesh screen, the over-size being returned to the bottom of the elevator and sent again through the disintegrator. The material which passes the screen is sent to a mixer, very similar in construction and operation to the ordinary batch mixer, where it is given a thorough mixing. It is then delivered to the hopper shown in the upper left of Fig. 6.

From this hopper it is withdrawn and put into bags. The bagging is done by means of the bagging scales shown in the figure. The hoop shown on the funnel-shaped attachment at the end of the scale arm can be clamped around the neck of a bag in such a way that the weight of the bag and contents will support it. When the bag is full—usually 200 pounds of fertilizer—the hoop is raised by a sharp blow and the bag drops off to be tagged, sewed and loaded in car or wagon for shipment.

A PRACTICAL METHOD OF FILING DATA FOR REFERENCE.

By J. Madison Taylor, A.B., M.D.

The plan here offered has been in use many years by me and my friends. It includes provision not only for unanimity in the assembling of choice data to be used by the collector, but can be lent to any one else. When the death of an industrious collector occurs, his data should be available by any one else working on similar lines. This last point, the ultimate disposition of valuable material, deserves especial attention.

And first is uniformity of method in the selection, arrangement and classification. My plan of procedure of assembly and bestowal might be agreed upon and adopted until a better one should offer. A considerable group of research workers would thus become able to interchange data, and to mutual advantage. This system has been found practicable among a group of my friends not all interested in medicine, but in correlated subjects such as genetics, psychogenetics, sociology, anthropology, and human economics. So excellent are some of these collectanea that we would deplore their dispersal or loss.

In my system the simple device is used of an ordinary commercial vertical filing case 12 inches by 16 inches. Wood material preferred as safer as a "flash fire" protection. This system or container is convenient for filing a full flat sheet, deleted from a medical weekly, 8½ inches by 11 inches. The standards are removed and the full sheet taken out. Related sheets are then clipped together and inscribed on the right side (which thus appears *up* in the folder, hence the inscription catches the eye). They are grouped in a threefold manner, thus: (1) a general classification; (2) a particular grouping; and (3) the specific topic all in manilla folders. More often the general subject is the only one stated. These are then filed by a secretary and await revision and disposition. These excerpts are taken from publications differing in size, but the maximum space of the commercial filing case suffices for medical and most other publications, scientific magazines and the like, from which material is taken.

I find it convenient to use three different colored folders to indicate (1) the general subject, a sort of "omnium gatherum" of heavy buff (manilla), (2) a pink one for selected or grouped subjects, and (3) a blue one for the particular aspect of the subject under consideration and also such memoranda, notes, partial manuscripts as should be kept together.

In the first reading of a journal my plan is to merely survey each article, to determine whether the subject or caption interests or not. Often one finds some parts of use, or some observation or hint, which I mark by a system of blue or red pencillings. This article is then removed, set aside, and it generally gets a second survey before it is filed (in buff manilla) and half the time is later, and should be, rejected. If it proves choice or suitable, it is further inscribed and goes into a pink, or even a blue folder. This routine, by the way, occupies so little time that eleven journals are disposed of and kept up to date with no waste of effort, now that the habit has become almost an automatic doing.

When I desire to inform myself on a special topic I can turn to the general subject (which generally occupies several manilla folders) and rapidly pick out special material to be placed in a pink folder, and when in haste I can run over these and get enough selected data for a blue one, and go to work. Note that materials thus assembled are original articles or at least first-hand abstracts, and among these will be found references to other articles or to text books and the like.

In providing space for general subjects some large topic may occupy an entire drawer, others only half a drawer. The lettered spaces can be reinscribed or specially labelled to suit. It is well to put all the manilla folders at the far end of a space, and together, since they are subject to constant revisions and rejections. The folders fluctuate in bulk as they become filed, and as distributions or rejections are made.

A number of useful devices were developed as experience grew but this outline may afford hints enough. Each individual making use of the system will devise yet others. The chief points I wish to emphasize are *the desirability of the adoption of some uniformity in arranging literary material,* also the wisdom of preserving such material after one has taken pains to assemble so much, he shall then be able to pass the collection on to others. It would seem to me that one who has made a considerable repository should notify the librarian of some central or local library specifying the subjects he has covered and any other pertinent facts, such as how large the stock is and what special topics the collector has been interested in. It may well happen that there is also a good deal of half finished, or pretty well completed manuscript. The title of these manuscripts should also be available. I keep such a memoranda, or table of contents in a blue folder. Should I pass out *now* my "heirs and assigns" would probably cast all this material in the rubbish heap. Another or many others however, might be most glad to get this data. I certainly would be glad to have had access to similar reservoirs and manuscripts.

STARCH FORMATION IN LEAVES, AND PHOTOGRAPHIC PRINTS.

Photographic prints from negatives can be made upon the leaves of living plants, thus putting in evidence the formation of starch in the leaves under the influence of solar light. The experiments can be carried out with especially good results by employing nasturtium leaves for the purpose, since these are found to have the desired qualities such as a good flat surface, thin substance and absence of small hairs on filaments, and these leaves will readily become discolored through the removal of the chlorophyl. Suitably chosen leaves are wrapped about with black paper in such manner as to protect them from the light for about two days, in which case all the previously existing starch is absorbed. Then the leaf is exposed to the sun for an entire day under a good strong negative, a portrait for instance, and the starch will now be formed anew at the expense of the carbon dioxide and water vapor of the atmosphere in the parts which are exposed to the sun, in quantity depending upon the strength of the light, which of course depends in turn upon the variable thickness of the negative. The leaf is thereupon cut off from the plant, scalded for one or two minutes in boiling water, and then placed in a bath of alcohol until it becomes discolored, since the chlorophyl dissolves in the alcohol. After this treatment, the leaf is dipped into a bath of iodine water diluted to about the color of strong beer, and the starch will become colored a blue-violet hue, thus forming a positive image. The process affords an interesting result and also sets forth the part played by the chlorophyl.

Fresh Information Concerning Yeast

Research at the Berlin Institute of Fermentation and at the Mellon Institute at Pittsburgh

PERHAPS the plant which has been longest cultivated by mankind is the yeast plant, although it is only in comparatively recent years that it has been recognized as being a plant, and it is still more recently that the nature of its activities has been understood; still, fermented products were doubtless used long before agriculture began. Extensive researches with respect to yeast have been occupying men of science in various countries during the last ten years particularly. Some of the results of these researches have already been laid before the readers of the SCIENTIFIC AMERICAN[1] especially with regard to the work done in Germany concerning yeast as a valuable food material, as a possible substitute for bone, ivory, etc., and as a source of fats, sugar and protein derived directly from substances. It is the purpose of the present article to supplement this information on the one hand by an account of the latest available knowledge concerning the researches conducted by the Berlin Institute of Fermentation with regard to the mineral yeast so loudly heralded, i.e. yeast grown from inorganic substances instead of being obtained as a by-product from beer, and on the other by a *resumé* of the work done at the Mellon Institute respecting the improvement in the quality of bread by the addition of certain mineral compounds which furnish a portion of the nutriment required by the yeast. As will be seen the German researches—more ambitious than those conducted in this country—while eminently successful in the laboratory, are as yet a failure economically. Whereas the group of chemists at the Mellon Institute have succeeded brilliantly in both bettering the quality and lowering the cost of bread by means of mineral nutriments for the yeast plant.

Yeast is a fungus which is very simple in organization. It consists of microscopic oval cells, three or four microns in length which multiply by budding and readily separate from each other. Yeast does not produce alcoholic fermentation directly but only under special conditions through the intervention of various disastases which it secretes. In normal conditions, i.e. when it is cultivated in the air it secretes only sucrase and it inverts sugar without causing fermentation. In this case it breathes like an ordinary plant, absorbing the oxygen of the air, setting free carbon dioxide, and consuming only the comparatively small quantity of glucose which it requires for its nutrition and doing this exactly like any other fungus which is not an alcoholic ferment.

But as soon as the yeast is deprived of air its respiration ceases and the secretion of zymase (a diastase having the property of breaking up glucose into alcohol and carbon dioxide) begins; the result of this is alcoholic fermentation. In this latter case the cell acts as a ferment and the cellular mutliplication is less abundant than in the first case.

The yeasts employed in breweries are the cultivated yeasts belonging to the species *Saccharomyces cerebisiae;* after fermentation they are deposited at the bottom of the vat, where they can be recovered to be employed again. Since they multiply during the process of fermentation there always remains under normal circumstances a certain excess which is used for preparing bakers' yeast.

* * * * * *

When it was first proposed to make use of yeast for human food and animal fodder in Germany, the excess product derived from the brewers was employed, being dried, sterilized, and if necessary freed from its bitter flavor. This product was of great service dating from November, 1914; when employed as cattle food it took the place of 60 per cent of the protein previously furnished by imported fodder in the form of cereals, hay, oil, fish meal and dried meat. This dried yeast contains from 6 to 10 per cent of water, from 50 to 60 of proteins, from 2 to 4 per cent of fatty substances, from 22 to 35 per cent of organic matters of non-protein character (especially of carbohydrates, of which 20 per cent on the average consists of glycogen), and finally of from 5 to 11 per cent of mineral ash, 2 per cent of the latter being phosphated substances. From 78 to 88 per cent, varying according to the animals concerned, are assimilable.

Brewers' yeast either fresh or dry has long been employed in medicine, especially in the treatment of boils. Invstigation has proved that the curative virtues of this are not due to the fact that it contains living substances, the "figured" ferments diastases, zymases; for the sterilized product retains all these medicinal values. When used as a human food, yeast can be consumed in amounts of as large as 100 gr. per day.

Germany contained not less than 80 factories for the drying of yeast. The dried yeast sold to begin with for 28 marks per 100 kg., but its price rose to 80 marks. It is dried in the same manner as milk in the preparation of powdered milk, i.e. by depositing it in a thin layer upon revolving cylinders heated by steam and provided with scrapers.

The manufacture of this yeast was checked when the breweries went out of commission because of the lack of raw material. These yeasts from the breweries were cultivated of course by the second method of proliferation described above.

Yeast cultivated by the first method in purely mineral mediums has received the name of mineral yeast. The possibilities of obtaining this so-called mineral yeast was demonstrated long ago, by Pasteur in particular. But in Germany the question was more urgent. It was necessary to produce the yeast rapidly and in great quantities, and it was also necessary that it should be as rich as possible in assimilable products.

After a dilute aqueous solution containing sulphate of ammonia, phosphate of potassium, salts of lime and of magnesia, and sugar (molasses) is planted with a very prolific yeast and is furnished with a sufficient amount of air, the yeast will develop rapidly without fermentation and without producing alcohol.[2] This yeast separated by a filter press and then dried is mineral yeast.

The raw materials which it is possible to employ include:

1. Instead of molasses the residual waters from the sugar houses, which contain not only a certain amount of sugar but also nitrogenous substances and salts of potash.
2. The residual waters of starch-works, which contain besides sugar nitrogenous compounds and mineral salts of nutritive value for yeast.
3. The residual lyes remaining from the manufacture of cellulose paste by the bi-sulphite process; these contain both sugars and nutritive salts.
4. Urine and purin, which serve particularly as a source of nitrogen.

All of these raw materials have been thoroughly tested since 1916, and have been found to yield materials readily, but in the laboratory alone and in industrial tests (as much as 30 cm. of the solution ever in operation at one time), abundant quantities of a yeast which animals become easily

[1]Transforming Sugar Into Proteins and Fats, *Scientific American*, Vol. 113, p. 446.
Deriving Fat from Yeast, *Scientific American*, Vol. 114, p. 101.
Buttons as a By-product of Yeast, *Scientific American*, Vol. 115, p. 423.
Dried Beer Yeast as an Article of Food, *Scientific American*, Vol. 79, p. 311.

[2]At any rate this is true in theory; in practice, however, when yeast is cultivated in purely inorganic mediums the proliferation begins with difficulty and proceeds slowly; while the reason for this is as yet unknown, it is probably due to an excess or a lack of some one of the salts. When yeast is cultivated in any sort of must on the contrary, such as that used in breweries, the proliferation begins at once and continues with great rapidity.

habituated to provided it be added to other foods to which they are accustomed.

Unfortunately genuinely industrial and commercial attempts at manuafcture, which took place during the sugar campaign of 1917, 1918, were a complete failure. It had been expected that 99 per cent of the sugars employed could be transformed in the course of from 6 to 8 hours into a dry yeast containing only 10 per cent of water. However, it was found that to accomplish this abundant aeration was required, and this could not be obtained except by the use of such powerful bellows as to render the process impossible from the technical and economic point of view. Furthermore when without the aeration the content of the yeast with regard to the proteins, already considerably less than in beer yeast, was reduced from 50 to 35 per cent, a considerable fraction of the combined nitrogen in the raw materials was lost; in fact, in the form of free nitrogen it passed into the atmosphere in the gaseous state.

Later attempts were successful in reducing the blowing required by means of a new method and the distribution of air upon the yeast within the technically acceptable limits, but the resulting yeast utilizes only 82 per cent of the sugars employed. These results remain to be carefully verified so that thus far the process cannot be regarded as commercially successful. The objection has been raised that it would be more advantageous to make use of the raw materials listed above either in the form of cattle food or as fertilizing material. The answer to this is that while this would certainly be a better form of utilization of the raw materials, it would subject their value to the uncertainties involved in farming, namely, the changes of the weather and the various diseases to which the cattle are subject, to say nothing of the fact of the much greater length of time involved.

Furthermore, mineral yeast is far from being worth as much as brewers' yeast. When dried its content of nitrogenous substance is rarely as high as 50 per cent; that of carbohydrates is also less; while that of water and mineral salts is much higher. Finally, comparative experiments with regard to its digestion and assimilation by animals and by men, either with or without the removal of the bitter taste, show that the total percentage of assimilation is always less, sometimes considerably so; for each of these groups are food substances, especially the fatty matters.

We are indebted for the data in the preceding paragraphs concerning the German process and results to an article in the *Chemiker Zeitung* of Berlin an abstract of which appears in a recent number of *Le Génie Civil* of Paris.

In 1911 one of the largest bread-making concerns in the United States, having bakeries in several cities, established a fellowship in bread-making at Mellon Institute, Pittsburgh. The work was continued for several years, with highly gratifying results, since the quality of the product was both improved and standardized, while the cost was lowered. These happy consequences were chiefly due to the furnishing of certain mineral substances which acted as a food supply for the yeast. The investigations in question were carried on by Messrs. Henry A. Kohmann, Charles Hoffmann, Truman M. Godfrey, Lauren H. Ashe, and Alfred E. Blake. Their conclusions were first made public in a paper presented in abstract by Mr. Kohmann, at the Urbana Meeting of the American Chemical Society, April 19, 1916.

The first important problem presented to this group of investigators was the effect of certain mineral salts, such as are commonly found in natural waters, upon the fermentative activity of yeast. The company referred to had been puzzled by the fact that it was found necessary to change both the quantity of yeast and the period of ferment in different localities in order to produce bread of as nearly standard quality as possible, in spite of the fact that the raw materials were identical. Investigation showed that variations in the activity of the yeast were due to the differences in the mineral content of the waters used in making the bread.

However, among the larger number of substances examined it was found that remarkably few exert any important influence upon fermentation in bread. The salts of the mineral acids, such as chlorides, nitrates, nitrites and sulphates exert practically no influence. The carbonates, which are very common in natural waters, are objectionable because they neutralize the acids of the dough and thus interfere with the progress of the fermentation, the carbonates of magnesium and the alkali metals being especially detrimental. The potassium salts were expected to exert a decided influence, especially the phosphates because of their high percentage in the ash of yeast, but were found to have only a very slight effect, that of the phosphates being not noticeable.

Because of their frequent occurrence in water the salts of the alkaline earths were studied in detail, with results of surprising interest, *particularly the calcium salts.*

CONCLUSIONS.

Before going more into detail it is advisable to put before the reader the most important conclusions arrived at during the research. These are five in number:

I. By the use of minute quantities of ammonium and calcium salts and potassium bromate in bread from 50 to 65 per cent of the usual amount of yeast can be saved.

II. Incident to the economy in yeast thus effected there is a saving of about 2 per cent of fermentable carbohydrates, calculated upon the total flour used, due to the greatly diminished consumption of these by the yeast.

III. The proper use of nutrient salts for the yeast gives greater control over the dough and aids in obtaining better and more uniform bread, regardless of locality.

IV. The added salts conserve the inherent qualities of the dough and consequently maintain its stability and strength to a far greater degree than by the old method.

V. The finished loaves are improved in quality, flavor, texture, bloom, and uniformity.

AMMONIUM SALTS.

Experiment proved that like many other acids glutamic acid matures or ages the dough and also increases the gas set free by the yeast. This accelerating effect was observed in bread and likewise in fermenting cane sugar, dextrose, and malt extract. In fermentation of this kind other acids failed to increase the fermentation as did glutamic acid hydrochloride.

So we were led to believe that it was not a matter of acidity but that glutamic acid hydrochloride owes its accelerating effect to this nitrogen content. With this idea in mind, we conducted baking experiments with other nitrogenous substances. Ordinary peptone such as is used for culture media, as already known, accelerates alcoholic fermentation greatly but this substance is expensive and, accordingly, attention was directed toward cheaper materials which would accomplish a similar result. The salts of ammonium were found fully as efficient as peptone.

Early in the research it was observed that the increased fermentation, due to the ammonium sulphate, matured the doughs in a much shorter time. Bread fermented 3½ hours with the use of ammonium sulphate was practically as mature as the control bread in 4½ hours. Obviously then, this salt can be used for the production of bread in a shorter time. On first thought one might infer that this action would be taken advantage of in increasing the output of a bakery; this, however, is not the case. The oven capacity, more than anything else, governs the productive power of a bakery. Although a short fermentation period is highly desirable to the baker shop, there is a limit beyond which it is not safe to go. Unforeseen delays are frequent in the daily operations and since these often occur when the dough is already working, over-fermentation is the result. The shorter the fermentation period, the greater will be the over-fermentation when delay occurs. In our opinion, according to present practices, the fermentation period should not be less than 4½ to 5 hours for hard wheat flours, excepting in special cases in which it is necessary to produce bread in a very short time to

meet rush orders. In general, the increased fermentation due to the addition of ammonium sulphate can best be utilized by reducing the amount of yeast that is ordinarily required.

In small quantities, the volume remains practically unchanged, while it is diminished by 1 g. or more. Alkalis are very detrimental in bread and this, no doubt, explains the inefficiency of ammonium carbonate. Moreover, it was observed that ammonium carbonate imparted an objectionable odor to the bread. The carbonate may be used successfully only when sufficient acid is used to neutralize its alkalinity.

Ammonuium fluoride accelerates the fermentation quite as much as other ammonium salts if used in small quantities; but in larger quantities it retards fermentation to a marked extent.

There was a decided increase in volume and gas production with the increase in the calcium chloride content of the dough. The texture, flavor, and general appearance of the bread were improved as well. The loaf volume was increased considerably more than the gas production, which would indicate that calcium chloride has an effect upon the gluten of the dough as well as upon the yeast. In the light of some experiments conducted by Hardy upon the effect of electrolytes on the strength of wheat flour, this seems highly probable.

It had been previously demonstrated by one of these investigators that the losses in bread-making depend to a large extent upon the amount of fermentation which the dough undergoes. In a normal fermentation the losses were found to be 5.15 per cent, while with the same flour the total losses were only 1.81 per cent when the loaves were placed into pans at once upon mixing. The bread obtained in this way was decidedly poor, as is always the case when it is very much under-fermented, and it was made in this way merely to detect any difference in losses due to fermentation. In self-rising bread the losses were found to be only 0.44 per cent. This difference in the losses of the two types of bread was explained as follows: (1) Yeast produces 1.04 parts of alcohol to every part of carbon dioxide, both of which are largely driven off during the process of baking, while in salt-rising bread there is no alcohol produced. (2) It is necessary to ferment yeast bread in the sponge and dough stages from 5 to 8 hours, and, as it is allowed to rise in loaf form in the pans but one hour or less, only a small part of the total gas produced is actually used in aeration, while salt-rising bread is made into loaves and placed in the pans immediately upon mixing the dough and very little gas is lost. (3) The gases produced by yeast consist of carbon dioxide, while those produced in the salt-rising bacterium consist of about 1/3 carbon dioxide and 2/3 hydrogen, which is only 1/22 as heavy as the former.

The fact that the losses in ordinary bread are dependent upon the amount of fermentation led us to suspect that with the use of yeast stimulants the decomposition of sugar would be less than in a normal dough, because the initial fermentation is much slower and the total gas production is less. With this idea in mind, we made three normal doughs and three with a reduction of 50 per cent in the usual amount of yeast and with 0.5 g. ammonium sulphate and 1.2 g. calcium chloride in 1,000 g. of flour. The gas evolved in the usual time from 50-g. portions of the doughs was collected in Bunsen gas holders and from the total weight of gas produced the quantity of sugar decomposed was calculated, assuming that the carbon dioxide evolved represented 45 per cent of the loss in sugar.

It will be noticed that the consumption in sugar is considerably higher in the control dough than in the one with added salts. The difference represents the saving in sugar that is effected by the use of ammonium and calcium chlorides in bread.

USE OF POTASSIUM BROMATE.

In connection with the use of these salts as yeast nutriments in bread-making, with special reference to the losses, mention will be made briefly of potassium bromate as used in conjunction with them.

In the fermentation of bread, a two-fold object is accomplished, namely, the maturing or aging of the dough and the aeration of the bread. The former is accomplished during the fermentation period, which takes from 4 to 6 hrs. in the best practice, and the latter during the proofing period, which requires from ½ to 1 hr. After the dough is sufficiently matured, or aged, it passes through the dividing and moulding machines, which press out practically all of the gas. Then it is put into pans and allowed to proof, and only the small fraction of the total gas which is produced while the bread is in the pans actually functions in aerating the bread. The effect of the potassium bromate upon the dough is essentially an aging, or maturing effect and is characterized by the exceedingly small quantities required.

Up to a certain point the gas-retaining power of dough and the loaf volume are increased by fermentation; then the dough becomes "rotten," i.e., it no longer retains the gas well and, accordingly, the volume is greatly reduced.

A desirable quantity of potassium bromate—say 0.015 g. per batch of dough containing 600 g. of water—ages the dough so decidedly that 25 or 30 per cent of the usual amount of yeast can be saved without imparting to the bread any of the characteristics of under-fermentation, such as heaviness, dark color and coarseness in texture. In fact, the bromate in these quantities improves the dough with respect to texture even though the yeast is reduced by 25 per cent. This pronounced effect is attributed to the oxidizing power of this salt, for it has been found that by passing oxygen through the dough a similar maturing action is obtained, but of a lesser degree. This is probably due to the condition of the oxygen—in one case we have molecular oxygen and in the other we have nascent oxygen—the nascent oxygen being more powerful than the molecular, and, therefore, having a greater maturing action on the dough. The effectiveness of the nascent oxygen is indeed surprising, for the quantity of the potassium bromate is so small that the total available oxygen is less than 1 cc. per loaf of bread.

When potassium bromate is used in addition to ammonium and calcium salts, it effects a saving in yeast of 25 to 30 per cent of the amount required without it. For instance, when 30 per cent of the usual amount of yeast can be saved with the yeast stimulants, the saving may be increased to 65 per cent with the addition of potassium bromate.

The aging, or maturing effect of potassium bromate upon the dough, without increasing the rate of fermentation or the sugar consumption by the yeast, results in a much greater saving in sugar than that due to the yeast stimulants alone.

Six hours' fermentation is the approximately normal period in the best baking practice, 5 hrs. in the dough state and 1 hr. after the bread is made up into loaves. The range between 5 and 7 hours' fermentation will cover most variations in baking process, due to the requirements of different flours and the type of bread desired. It is clear from the results cited above that the losses increase as the fermentation proceeds and that they are uniformly lower in the new process. The difference in the average losses between the two processes are 2.23, 2.25, and 2.22 per cent in 5, 6 and 7 hours respectively, which is practically a constant. This is to be explained by the fact that after 5 hours the rate of fermentation in the two processes is practically the same. The difference in decomposition of sugar occurs mostly in the initial stages of the fermentation before the nutriments greatly accelerate the activity of the yeast.

It will be noticed that with the normal amount of sugar and added salts the bread is much richer in this substance than the control, while if 2.25 per cent less sugar is used in the batch, the bread is slightly richer in sugar than the control bread.

It is interesting to note that for several hours there is an *increase* in the sugar content of the dough, the old process

reaching a maximum about 2 hours after the dough is set and the new one at about 4 hours. In the light of this fact, it is evident that sugar analyses upon dough cannot serve as an index to sugar consumption by the yeast. The results are of interest, however, in demonstrating the activity of diastatic enzymes; in the new process the sugar content is higher at the end of the fermentation period than at the beginning, showing that the production of sugar is greater than the consumption; in the old process, this does not obtain, as there is nearly 1 per cent less sugar at the end. The difference in the sugar content between the two doughs at the beginning is due to the fact that less sugar is regularly used in the new process.

The economic saving possible by the proper use of nutrient salts, in the advent of a rather general adoption, sums up to surprising figures. Take, for example, the saving in sugar on the average flour production of the State of Kansas—say 20 million barrels or nearly 4 billion pounds. A saving of 2 per cent on this amount is 80 million pounds, and it is mainly sugar that is decomposed and thus lost in bread-making. The ecenomies in the yeast are greater than those in the sugar. Even the moderate use of such a process means a considerable saving to the country, and is a step toward conservation of resources. At the present time, this process is used commercially in the manufacture of more than a million loaves daily.

A further advantage incident to this process of bread-making was observed in the increased stability and stiffness of the dough.

The new process has been used for breads of various types, such as pan breads, Vienna and French breads; also for rye, Graham and whole wheat breads. Likewise, it has been used with spring, winter and Kansas flours, and the different grades of flour, and has been found to be universally applicable.

In connection with the different grades of flour, it should be said that the process cannot be used to give bread the appearance of being made from a higher grade of flour than is actually employed. The improvement in color with the use of the new process is due to the improvement in texture and cannot be regarded as a bleaching process. The grayish color of the lower grades of flour remains in the bread made by the new process just as it does in the usual process. By any process, the color of the crumb is improved by fermentation up to a maximum and in the new process the same changes are noted; much less yeast, however, is required to accomplish the desired results.

The practical application of the new process has met with success, and it is now in operation in a large number of bakeries. A number of these are under the direction of one superintendent, who claims that the process has been of material aid in standardizing the manufacture and maintaining uniformity of the bread in the different localities. As already stated, certain differences were noticed in the bread in a chain of bakeries, although all the raw materials were identical. These have been practically overcome by the new process, which virtually standardizes the water used for the baking purposes. This would be expected, because the required nutriment is supplied by means of these salts used as yeast food, and the addition of further mineral matter, either through the water or otherwise, has less and less exect as the quantities increase. It is a general rule that, in the addition of nutriments or activators in steps, the first portion added has a correspondingly greater effect than the succeeding portions.

For the sake of convenience and accuracy in the use of these salts, they are in practice mixed with flour and salt, so that it requires 8 oz. of the mixture for 60 lbs. of water, or approximately 160 lbs. of bread.

It is but natural to inquire: What becomes of the chemicals during the fermentation and baking of the bread? The purpose of the ammonium salt, as already stated, is to supply the nitrogen required by the yeast and it is of interest to know whether any of it remains in the bread.

Bread No. 1 was made by the new process and it is not as high in ammonia as No. V made without yeast nutriments. None of the breads has an ammonia content that it is at all significant.

The state of combination of calcium in the bread is scarcely subject to question. It has been shown by Teller[3] that the phosphoric acid in flour exceeds by ten times the calcium and it may be safely said that even by the use of the new process, the bread contains several times as much phosphoric acid as is required to combine with the calcium. Under those conditions, the potassium phosphate of the wheat undoubtedly interacts with the calcium sulphate, as it does in wort,[4] in accordance with the following equations:

$$KH_2PO_4 + CaSO_4 = CaHPO_4 + KHSO_4$$
$$2K_2HPO_4 + 3CaSO_4 = Ca_3(PO_4)_2 + K_2SO_4 + 2KHSO_4$$

It is known[5] that the calcium requirements of the body can be supplied by inorganic as well as by milk calcium. Abderhalden[6] has demonstrated taht the complicated organic substances of our foods are replaceable by the simplest structural materials and that these are built up into various tissue substances. It should be mentioned in connection with the use of calcium salts in bread that Rudolph Emmerich and Oscar Loew[6] advocate the use of calcium salts in bread from a purely dietetic standpoint.

The increased lime content of bread by the use of the new process is a very happy coincidence, even though incidental. Unfortunately in modern methods in milling, the greater part of the constituents of wheat is lost to white flour. As indicated by Teller,[7] seven-eighths of the phosphoric acid and eleven-fourteenths of the potash and lime of wheat are found in the stock feed; consequently, a partial restoration of the lime in white bread must be considered highly desirable.

ARTIFICIAL CAMPHOR

THE word camphor was long applied rather indiscriminately to a large number of solid products extracted from natural essences. At present, however, it is conned to the product obtained from the "camphor tree" or *Laurus camphora* which is grown in Japan on a large scale and which is also being planted in Sumatra, Java, and Borneo. Other plants contain this compound, which is often found mixed with borneol. Among such plants are the rosemary, the feverfew, and the sweet marjoram, but it is from the laurel camphor that practically all of the drug used throughout the world is derived, thus giving Japan a virtual monopoly of it.

In recent years the consumption of camphor has considerably increased, while the production has diminished, the result being a rise in the price of the drug and a more intensive cultivation of the tree. But in spite of the new plantations the situation has grown steadily worse. This is, of course, largely due to the fact that the extraction of the camphor entails the total destruction of the tree, since not only the branches but likewise the trunk and the roots are subjected to the action of steam. Unfortunately the trees cannot be utilized until they are from 100 to 150 years old, so that the young plantations set out within the last few years furnish no immediate source of supply. An attempt has been made, but without much success to avoid the destruction of the tree by distilling the camphor from the leaves.

These circumstances have naturally given an impetus to the manufacture of synthetic camphor, which made but little headway so long as the price of natural camphor was low. A study of this subject by a Professor Mailhe appeared in the *Journal des Usines à Gaz* (Paris) of January 20th, 1920. We are indebted to *Le Genie Civil* (Paris) of February 21st, 1920, for the following resumé:

[3]Ark. Agr. Expt. Sta. *Bull.* 42, 70.
[4]Matthews "Manual of Alcoholic Fermentation," pp. 194 and 195.
[5]*Biochem.* Z. 9, 185-207.
[6]Wien. med. Wioch. 62, 177.
[7]Ark. Agr. Expt. Sta. *Bull.* 42.

Perhaps no substance in the entire range of organic chemistry has been the subject of such extensive research as camphor. Partial syntheses of camphor starting with camphoric acid are not difficult to make but they bear no relation to the *industrial* manufacture of artificial camphor.

Camphor, deposited from the oil of camphor obtain by distilling the wood with steam, is a solid substance which melts at 177°C. and boils at 207°C. It polarizes light to the right. Its formula is $C_{10}H_{16}O$. Being of cetonic function its hydrogenation leads to a secondary alcohol, namely, *borneol.* As usual with secondary alcohol the latter undergoes dehydratation, yielding a terpenic carbide, *camphene.* These reactions indicate that there is a very close relation between camphor and camphene, and that this relation is of capital importance in the obtaining of artificial camphor.

Reciprocally, when camphene is subjected to a hydratating action, by means of sulphuric acid, it yields either borneol or the isomer of the latter, iso-borneol, and this, when oxidized, produces camphor.

Evidently then camphene constitutes the primary raw material required in making artificial camphor. However, this terpene exists only in small quantities in certain natural essences, from which it would be difficult to extract it in the pure form. It is now prepared, therefore, by starting with the esence of turpentine which contains "pinene" or turpentene a carbide, which is an isomer of camphene.

The preparation of artificial camphor comprises three steps: 1. the production of the camphene; 2. its transformation into borneol; 3. the passage of the latter into camphor.

1. When gaseous hydrochloric acid reacts upon the pinene contained in the esence of turpentine, it forms a solid hydrochlorate with the liberation of heat. In order to transform this hydrochlorate of pinene into camphene a great many methods have been devised: thus soda and potash in alcoholic solutions produce this reaction; it can also be effected by acetate of lead dissolved in crystallizable acetic acid, by ammonia, by pyridine, and by piperidine.

2. The transformation of camphene into borneol consists in a simple hydratation. The method which appears to be best from the industrial point of view consists in heating in a water bath the camphene together with glacial acetic acid in the presence of a small quantity (about 2 per cent) of sulphuric acid.

3. The transformation of borneol or of iso-borneol into camphor consists in the well known problem of the oxidation or of the dehydrogenation of the secondary alcohol.

The oxidation can be exected by the various agents in ordinary use, such as air or oxygen, in the presence of a catalyzer, ozone, or a solution of permanganate of potash in acetic acid or in acetone.

The catalytic method of the dehydrogenation can likewise be employed with success. In this the vapors of the borneol or iso-borneol are made to pass over finely divided copper, heated to a temperature of from 300 to 330°C. which causes them to split up into hydrogen and camphor. If the operation is properly conducted it is possible to obtain practically pure camphor at once. This method might be employed with advantage in the transformation of certain natural camphors which contain rather large amounts of borneol; and which are upon this account difficult to use and are, therefore, sold at a very low price. By passing the vapor of these mixtures of camphor and borneol over copper heated to the aforesaid temperature, purè camphor would be obtained.

It would seem that this catalytic process, which is much less expensive than the oxidation process as well as easier to handle, must eventually receive the application it merits in the synthesis of camphor.

In brief the manufacture of artificial camphor comprises three series of well known reactions all of which are comparatively easy of application.

Since the raw material consists of turpentine the price of the artificial camphor would be governed by the price of the former. Before the war it was sold in France for 55 francs per 100 kg.; today the price is 600 francs and is steadily going up. The price of hydrochloric acid has likewise gone up. Nevertheless, it seems certain that the manufacture of synthetic camphor can be revived with an expectation of success.

The process of manufacture as described above has undergone certain variations. The most important of these is that which passes directly from the hydrochlorate of pinene to the acetate of bornyle by means of the action of lead acetate.

In this manner one stage of the manufacture is eliminated, since in this reaction, which is made in an acetic medium, the isomerization into camphene and the acetylation of the latter take place at the same time.

Other synthesis also have been effected, and like the foregoing they always lead to a camphor which is inactive with respect to polarized light, to a racemic camphor.

The original article from which this abstract is made contains a number of chemical formulae which we have not deemed it necessary to quote here.—Editor.

WHEN TO HEAT WOOD BEFORE GLUING.

Whether a hide glue joint will be strengthened or weakened by heating the wood before gluing depends on the size of the joint. It is assumed, of course, that the work is being done in a glue room that is warm and not draughty, and that the wood itself is at room temperature. Under these conditions, if the joint to be made is of small area, heating the wood is unnecessary. In fact it may be detrimental, for the warmth of the wood will keep the glue thin; and, when pressure is applied, too much glue may squeeze out, leaving a starved joint. It is very easy to apply too much pressure to a small area.

In making glue joints of large size (several inches each way), heating the wood before gluing is of distinct advantage. Many experiments at the Forest Products Laboratory, Madison, Wis., have proved that when the wood in large joint work is not heated, the joints develop full strength only in spots. Weak spots and even open joints are too frequently discovered.

Uniform high strength in joints of large size may be secured by heating the wood in a hot box for 10 or 15 minutes at 120 to 130 degrees Fahrenheit just before gluing. The heat from the wood prevents the glue from chilling and keeps it liquid until pressure is applied.

It should be remembered that heating the wood retards the setting of the glue to some extent. In heavy woods, from which the heat escapes slowly, this retarding effect is more marked than in lighter woods. In all species glued cold at the laboratory the time under pressure required to develop full joint strength was less than 8 hours. When heated wood was used at least 10 hours were required to develop full joint strength in mahogany, and more than 12 hours in red oak and maple.

PULP OUTPUT REDUCED BY LONG STORAGE.

How large a loss may be caused by decay in pulp wood through storage was learned in recent observations conducted by the Forest Products Laboratory at a sulphate pulp mill.

Pulp wood which yielded over 3½ tons per digester when used green, after a year's storage yielded only 3 tons. Some which had been stored from 2 to 3 years yielded only 2½ tons per digester. These losses in production, amounting in the latter case to over 25 per cent, occurred without any compensating reduction in operating expenses. Hence the monetary loss was fully equal to what the lost product would have sold for f. o. b. mill.

Such losses can be largely reduced by so operating the wood yard that the wood is used as nearly in rotation as possible, without allowing any to remain in storage as long as one year.

By-Products Coke

Recovering Valuable Products from the Gases Distilled from Coal

By J. F. Springer

ALTHOUGH one of the most abundant elements on earth, carbon is not always easy to obtain, especially if it is desired to have it pure.

Wood charcoal may be taken to represent an effort to produce pure carbon and wood charcoal can doubtless be used as a means of reducing iron ore to pig iron, but it is quite expensive. Bituminous coal contains carbon in two forms. Ordinarily, it also contains a substantial percentage of sulphur. Quite aside from the non-combustible content known as "ash," the carbon is thus associated with other substances. Usually, the important associates are sulphur and hydrogen, the hydrogen occurring in chemical combinations with carbon. Altogether, raw coal is unsuited to the manufacture of pig iron. The blast furnaces require carbon, but sulphur and hydrocarbons are not wanted. Accordingly, it has become customary to separate, as far as is commercially possible, these undesirable substances from the main body of the coal, for the purpose of obtaining a fairly pure carbon. The process employed is coking. By raising the temperature of the coal and at the same time preventing oxygen from reaching it, the hydrocarbons will be driven off in a gaseous form and the sulphur content will be reduced.

There are two principal systems of coking. In the one, no effort is made to save anything but the coke. Valuable hydrocarbons are burnt as they leave the body of coal under treatment, or simply escape into the general atmosphere. In the other system, more or less of the associated material is saved; so that the process yields coke and coal tar and other substances. The simpler system has been developed greatly in the United States and has in fact been in the ascendancy until quite recently. The coke produced is of excellent quality. Probably no other method excells the best American practice in the point of the quality of the coke. The quality relates, in part, to the structural strength of the pieces of coke. It is important in blast furnace practice that the layers or strata of coke in the stack be firm and strong so as not to yield unduly to the superincumbent masses. The type of furnace developed in the United States for the production of coke by the simple method described is known as the bee-hive oven. A typical bee-hive oven consists of a domed structure of brick with two openings, one at the highest point of the dome and the other on one side at the level of the floor. This side opening is for the removal of the coke after it has been made in the interior of the oven, and is temporarily bricked up during actual operation. The top opening provides for charging the oven with a fresh supply of coal and for the exit of gases and flames. The charging is a simple affair, consisting of simply filling the interior up to a specified level. As the floor tilts towards the side opening, the removal of the finished product is not difficult. A few days suffice for a complete cycle of all operations. The simplicity and ease of management and the high quality of coke have together conspired to retain the bee-hive oven in American favor long after Europeans had developed the by-product oven to a high state of efficiency. The by-product oven was not seriously considered in the United States, despite its success abroad, until about 1893. But since that time, it has steadily grown in favor, until in November, 1918, the by-product oven produced 2,500,000 tons of coke. This performance gave it the supremacy for the first time over the bee-hive oven. This crossing of the curves of output may be taken as indicative of a permanent change of relative positions. At the same time, it may turn out that the bee-hive oven will never become obsolete. It satisfies too many requirements of a practical nature.

The by-product oven is, necessarily, a complicated affair, more or less difficult and expensive to build and maintain. Moreover, its operation requires skilled attention. There are various varieties of this type of oven. Some perform one function; some, another, dependent partly on the content of the particular coal coked and partly on the available market. Coke ovens in the Pittsburgh district would perhaps find the by-products of very secondary importance, because of the market for high grade blast furnace coke. A by-product oven plant in the vicinity of New York City would be very differently situated. It would have some choice of the raw material, as the coal in any case would have to be shipped to it. There would be no blast furnace market of any size. This latter case may be illustrated by an actual example.

A large plant has lately been built and equipped on the meadows near Jersey City. The plant produces: (1) coke for foundries, blast furnaces, cupolas, steam plants, domestic

SEALING THE DOORS OF A BY-PRODUCT COKE OVEN BEFORE TURNING ON THE HEAT

stoves; (2) gas for consumption in homes and business offices; (3) tar, from which such products as creosote oil, various other oils, pitch, lampblack and dyestuff raw materials may be obtained; (4) ammonium sulphate, which finds service as a fertilizer material, as a refrigerating agent, etc.; (5) benzol, which may be used as a dilutent of gasoline for motor use, etc.; naphthalene, useful in the manufacture of dyes and moth balls. Here we have quite an array of by-products, some of them quite valuable. Coal containing high relative amounts of hydrocarbons is employed as the raw material. It comes from the Pittsburgh and Clearfield districts. The plant is on the Hackensack River, one mile from Newark Bay. The Erie, the Lackawanna and the Pennsylvania railroads are all within easy reach. Coal may be shipped to the plant by all-rail routes or by a route carrying it first to a tidewater terminal port in New York harbor by rail and thence by boat or barge to the water-front of the plant. A certain amount of economy is possible by utilizing incoming coal cars and barges as outgoing coke carriers.

This plant is a very considerable one, consisting of 165 ovens arranged in a single row, divided into three sections of 55 ovens each. Each section is termed a battery and is operated as a unit. The length of time required for coking is around 16½ hours, which is in marked contrast to the time required by the bee-hive oven. It has been estimated that, with 165 ovens operating on a 16½-hour cycle, the daily output is 2,200 tons of coke, 16,500,000 cubic feet of surplus gas having a thermal value of 610 b.t.u. per cubic foot, 75,000 pounds of ammonium sulphate, 24,000 gallons of tar and 10,000 gallons of light oil. All this comes from a daily input of 3,000 tons of coal. As to economy, it is claimed that the tar and ammonia pay for the operation and maintenance.

DUMPING THE QUENCHED COKE

Just across the river from the plant are located plants of the Public Service Gas Company and of the Public Service Electric Company. The big coking plant receives operating current from the one (submarine cables being used for transmission), and supplies gas holders of the other with illuminating gas. A tunnel beneath the river provides a crossing for the pipe lines carrying gas.

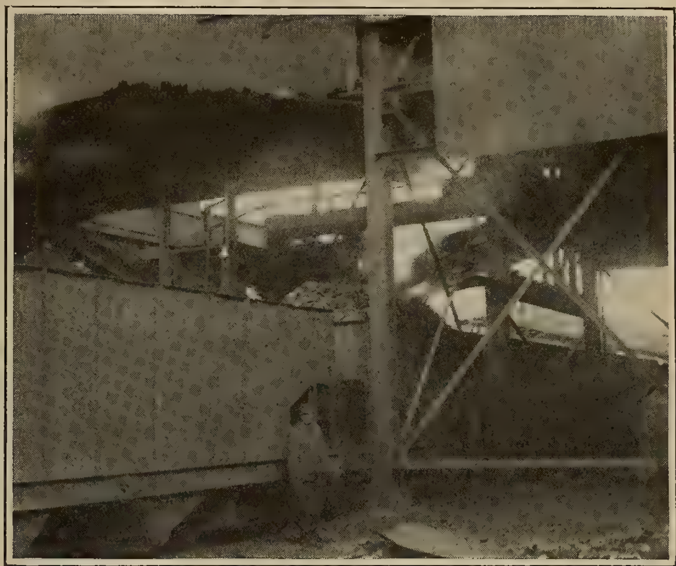
It may readily be imagined that it amounts to a real problem to keep this great plant supplied with its daily quota of coal. While coal comes in by water and rail, as already intimated, it is necessary nevertheless to have a stock on hand to tide the plant over inequalities and actual stoppages of delivery. There is, consequently, a stock-yard of 150,000 tons capacity. Ordinarily, the barges coming in with coal are able to continue service all through the winter; but, in 1917-1918, the weather became so severe that no barge was able to bring in coal for a period of seven weeks, although there were 7-foot tides at intervals. It is well, then, that entire dependence is not put upon the supply by barge, and that the railroad and the storage yard are also available.

Coal in the storage yard is piled normally to a height of 30 feet. But 40 feet is permissible without serious interference with the mechanical arrangements for reclaiming the coal. The wharf at which the coal barges discharge is 800 feet long. Here, as many as 24 barges may be docked at a time. But, this is not to be understood as 24 1,500-ton barges. The unloading tower which deals with the incoming coal barges is equipped with a big clam shell bucket competent to grab 5 tons of coal at a time. This bucket is electrically operated and is able to unload 600 tons of coal per hour. The bucket itself weighs 7 tons, is 14 feet high and is when open 15 feet wide. This monster bucket delivers to a big hopper and the hopper in turn delivers, through a suitable regulating gate, to a system of pan conveyors. The conveyor pans are 36 inches wide, as are also the belts to which they deliver and which traverse a big system of interlocking conveyors, located between the tower and the mixer building. At a suitable point in the conveyor arrangements the coke is weighed and the weight recorded by a belt scale. From data obtained from such records, the rate of stocking has been ascertained to be some 450 tons per hour.

The stock yard is 1,200 feet long and is filled by means of two horizontal conveyor belts. The one belt carries coal 450 feet, when it trips to the stocking and reclaiming bridge or to the second stock conveyor or else by-passes coal to two incline belts which supply a breaker. The second conveyor covers the remaining 750 feet, is reversible and handles coal and coke.

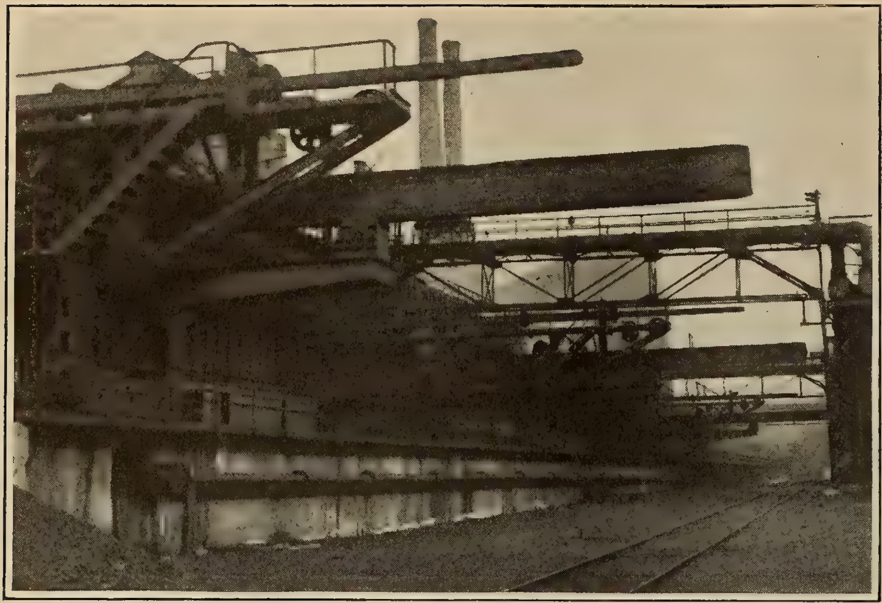
The bridge is a big affair which extends across the shorter dimensions of the yard and which may be shifted along the 1,200-foot length. In fact, this bridge may be skewed 20 feet either way, but is automatically prevented from being thrown further out of normal position. The bridge is, at one end, equipped with a stocking boom which extends over one side of the storage space towards the center. A grab bucket is operated to transfer coal along the 215 feet of bridge not covered by the stocking boom and may be used to reclaim to the stocking belts. The unloading of railroad cars is provided for by means of two hoppers which receive from the cars and deliver to a pan conveyor and inclined belt.

The coal as it comes from the mines is, not all of it, quite ready for the ovens. Coal delivered at the top of the crusher and mixer house passes over a screen which separates the fine from the lump. The lump coal is delivered to a breaker. This is an interesting device which consists in part of a revolvable inclined cylindrical screen. This is 12 feet in diameter and 17 feet long and is provided interiorly with shelves which serve to carry the coal up the incline. From the screen the coal drops 10 feet upon steel plow points. Coal that is more or less broken up has, as it moves along inside the screen, opportunity to drop through 1½-inch perforations. There are two short belts which carry fines from the breaker to any one of three mixer storage bins.



LOADING THE COKE INTO THE CARS

The coal is mixed and then beaten to very small sizes in two hammer mills. The first consideration in a plant like this concerns the chemical composition and coking quality of the coals; but the second has to do with the mixing and the degree or degrees of fineness. The hammers are of high carbon steel and at their tips have a linear speed of 2¼ miles per minute. There is a screen arc plate whose raising and lowering affects the size of the crushed coal. So much for the mechanical equipment employed in getting the coal from storage, barge or cars to the ovens.



THE "PUSHERS" WHICH TRAVEL ACROSS THE FACE OF A BATTERY OF OVENS AND PUSH THE COKE OUT OF THE INDIVIDUAL OVENS

PUSHING THE COKE INTO A QUENCHER CAR ON THE OPPOSITE SIDE OF OVEN

Leaving the ovens, the coke passes over 13 coke conveyors which make use of a total of 4,250 feet of belting. These conveyors, if run at capacity, demand 27,500 kw.-hrs. of current per month.

The coal, mixed and crushed, is delivered in weighed quantities to the ovens. That is, a big 15-ton specially designed larry car conveys the coal in its four conical hoppers to four charging holes in the tops of the ovens and there discharges through its quick-dumping gates. The lids belonging to the holes are removed prior to the arrival of the car. The coal runs down into the oven, whereupon a long steel bar is operated to level off the piles. After the leveling bar has done its work, the small door through which it was operated is closed, as are also the four lids of the charging holes. Just as soon as the fourth lid goes into place, a certain valve is opened and the way is left clear for the outward passage of gas, *via* a 13-inch pipe, to a big steel collecting main. There are two types of colecting main—the lean and the rich mains. During the earlier half of the coking period, the gas made has a high calorific average, the thermal content being put at 610 B.t.u. per cubic foot at standard atmospheric pressure. This is the rich gas and is collected by the rich main. During the latter half of the operating period, the average thermal content drops to, say, 525 B.t.u. This gas is passed into the lean main. A certain amount of this gas is required to provide for the heating of the ovens themselves.

Control of the temperatures of the ovens permits a schedule to be made of the cycle of operations. Thus, the whole period may be set to occupy a time which may be varied within not very wide limits around 16 hours. At the termination of the pre-determined operating period, the valve admitting to the lean main is closed, and the four charging lids are pushed to one side. Also, the big brick-lined doors at the two ends of the oven are taken off. One side of the oven is the "coke side." There is, on the coke side, a steel guide or rack, through which the new coke is shoved by a heavy ram operated by power. The ram pushes the hot coke into a steel quencher car. The mechanical device which pushes out the new coke includes other functions in its duties. It operates on tracks which parallel the batteries of ovens and in addition to pushing, levels the coal and takes off the doors. The car which receives the coke is of steel, has a sloping bottom and is equipped with side dumping doors. The dumping is accomplished by a compressed-air device, supplied with air from a compressor located on the electric locomotive whose business it is to haul the quencher car. When the car load of fresh coke is hauled over to the quenching station, a big shower-device is operated and the nine tons of red hot coke is in one-half minute cooled to a point where the remaining heat is but little more than enough to drive off the surface moisture, the quenched coke retaining about 3 per cent moisture. The car is next hauled to a place of discharge, where the load is dumped upon a sloping surface. From this last, it may be drawn off as desired and carried by conveyor or belt to the screens.

It will be understood that the coke thus produced is the main thing. It is, in fact, the fixed carbon of the raw coal. The remaining carbon content is all in the by-products, which are non-solids. With the bee-hive oven, the coke is the whole of what remains at the close of operations, except of course the ash. In the present type of by-product oven, the gas, ammonia and other volatile substances are driven off by the heat of the oven. They pass through long steel pipes to points outside the by-product building where primary coolers operate to reduce the temperatures. From the coolers, the by-products pass to the exhausters which are inside the building. From the exhausters, the gas under pressure goes through extractors which remove the tar, through reheaters and through saturators. All these operations are carried out inside the building. The gas is next sent outside to certain direct coolers, benzol washers and purifiers. It is now ready for a gas-holder, whose capacity is 30,000 cubic feet. The gas has now been cleaned and purified and has received a certain amount of enrichment. In short, it is ready for the consumer. Booster engines drive it through mains laid in the sub-sqeous tunnel underneath the river and into storage holders of the Public Service Gas Company.

The exhausters mentioned above draw the gaseous substances from the ovens, causing them to pass through the primary coolers which operate by the passage of cold water through tubes. The temperature of the gas is thus brought down automatically to 66°F. This one cooling operation suffices to separate most of the tar, ammonia liquor, moisture and naphthalene. As the gas, relieved now of a great part of its load, passes through the exhausters themselves, the temperature goes up some 12 or 13 degrees. The special tar extractors next operate to separate out the residue of tar. Preparatory to passage through the saturators, the gas has its temperature raised to 140°. The heating is done by means of steam heated tubes. In the lead-lined saturators, the gas is caused to pass through very dilute sulphuric acid. The saturator operates, through a chemical reaction between ammonia in the gas and the sulphuric acid, to extract all but a small percentage of the total ammonia. The ammonia as recovered

is ammonium sulphate in crystal form. The white crystals are washed in water to remove the free acid, after which operation they are dried in centrifugal hydro-extractors. Ammonium sulphate is an important refrigerating agent used in certain ice-making and refrigerating systems.

The plant includes a special laboratory building devoted to experimental investigation and routine chemical tests. A second laboratory is connected with the benzol plant and takes care of the special testing required in connection with benzol. At the benzol plant is recovered the light oil forming part of the by-products. This oil is made up of benzol, toluol, etc. Both benzol and toluol may be used as diluents of gasoline used for driving motors. Whether it is profitable to use them thus, depends naturally on relative prices. Benzol and toluol have also importance in dye manufacture. Toluol is the basis for the manufacture of TNT (trinitrotoluol) the violent explosive. The broad method of extracting the complex light oil is of interest. The gas from the saturators is "washed" with an oil adapted to absorb the light oil, and the mixture is then treated in a suitable still, which operates to drive off the light oil. The absorbent employed is a paraffine oil having a high boiling point. Naturally, the high boiling point is necessary, so that the whole of the light oil may pass off as vapor without carrying absorbent oil with it.

BROWNED ALUMINUM.

TO PROTECT aluminum and aluminum alloys from corrosion, L. von Grotthuss has tried the experiment of browning the metal electrolytically. The aluminum is suspended in an electrolyte consisting of a sulfur compound of molybdenum and zinc is used for the anode. The cell is maintained at a temperature of 60° to 65°C. The aluminum is soon covered with a dark brown coating. The metal may be bent or rolled without cracking the coating. A piece of aluminum thus coated was immersed in a salt solution for two months without showing the slightest trace of corrosion.—Abstracted from *Metall und Erz,* Jan. 22, 1920.

FUEL VALUE OF WOOD.

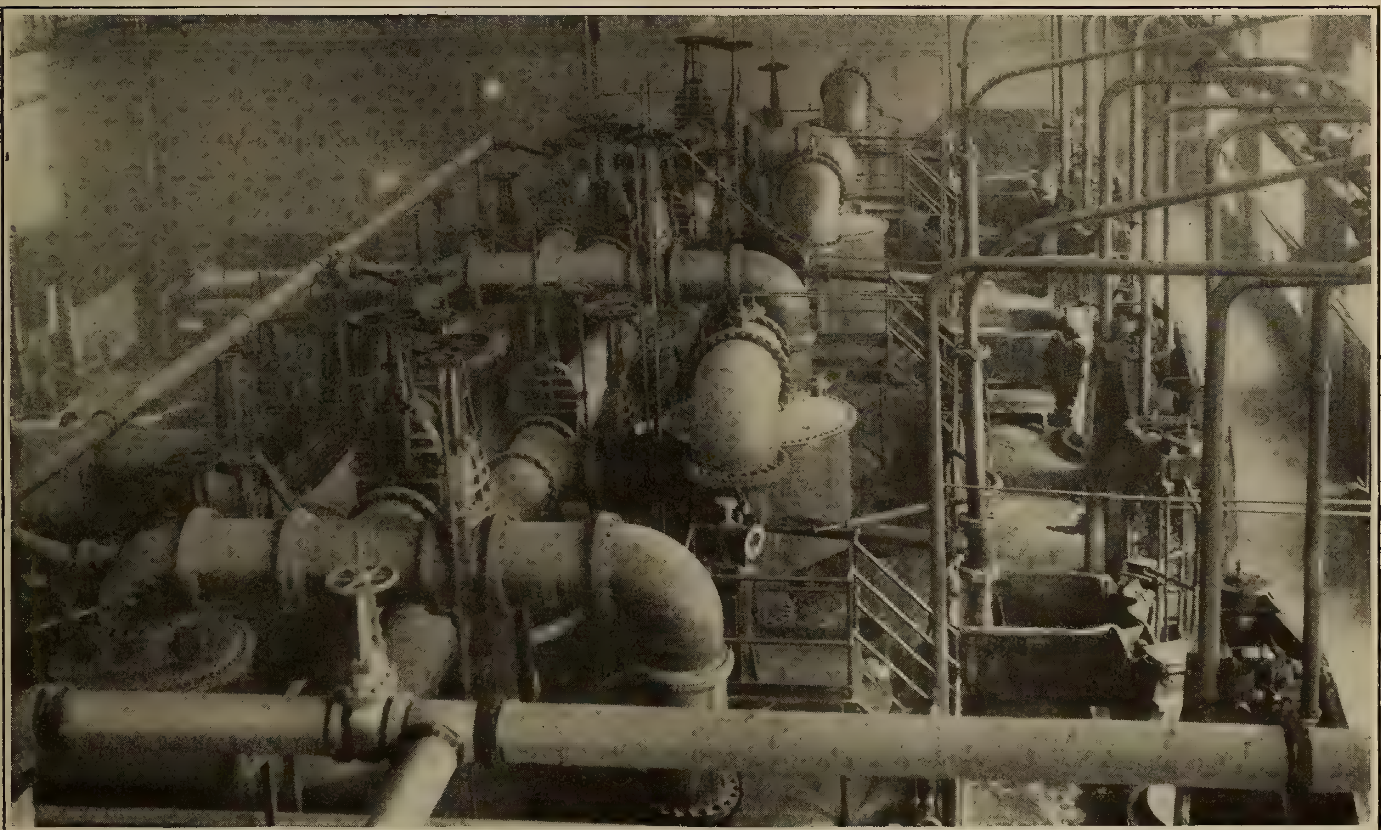
Two pounds of dry wood of any non-resinous species have about as much heating value as a pound of good coal. Speaking in tons and cords, a ton of coal may be taken as the equivalent in heating value of 1 cord of heavy wood, 1½ cords of medium weight wood, or 2 cords of light wood.

The following table is an approximation of the number of cords of seasoned wood of various kinds needed to give the same amount of heat as a ton of coal, on the basis of 80 cubic feet of wood, with a moisture content of 15-20 per cent to the cord:

1 cord	hickory, oak, beech, birch, hard maple	ash, elm, locust, longleaf pine, cherry	= 1 ton coal
1½ cords	short leaf pine, western hemlock, red gum	Douglas fir, sycamore, soft maple	= 1 ton coal
2 cords	cedar, redwood, poplar, catalpa	cypress, basswood, spruce, white pine	= 1 ton coal

Resin gives twice as much heat as wood, weight for weight. Hence such woods as the pines and firs have more heating power per ton than non-resinous woods. The resinous woods in the table are considered as having an average amount of resin (15 per cent).

The fuel value of wood depends in many cases not alone upon its heating power, but also upon such qualities as easy ignition, rapid burning, freedom from smoke, and uniform heat. As a rule soft woods burn more readily than hard woods, and light woods more readily than heavy woods. The pines give a quicker, hotter fire and are consumed in a shorter time than birch; whereas birch gives a more intense flame than oak. On the other hand, oak gives a very steady heat and is one of the most satisfactory fuels.



THE BY-PRODUCT PLANT INTO WHICH THE GASES FROM THE OVENS ARE CONDUCTED AND THERE DISTILLED TO RECOVER THE VARIOUS BY-PRODUCTS

Some Phases of the Fuel Problem*

Relative Advantages of Oil and Powdered Coal

By George A. Orrok

IN the early days of central-station development it was maintained that the cost of fuel was such a small percentage of the average sales price of electricity to a customer that it hardly paid to go to the expense of condensing engines, as the saving incurred was not warranted by the increased fixed charges on the installation. In those ancient days the fuel, while possibly the largest single item, did not exceed 10 per cent of the average sales price to the consumer, today our average prices are so low and the progress in economical power generation has been such that the fuel cost, still the largest single item, is 25 per cent of the average sales price to the consumer. And the fuel cost is still mounting. The cost of mining, increasing values of coal lands, restrictions of output, increases in the freight rates and cost of handling have more than trebled the price of coal to the Eastern companies and these increases have more than balanced the economies shown by the labor designs and arrangements of central-station apparatus.

It had been considered by most engineering authorities that the fuel problem for our larger companies had been definitely settled and along fundamental lines. The steam generator may be considered as perfected, especially as efficiencies as high as 80 per cent to 82 per cent are attainable under test with all of the types of boiler at present used in central-station practice. These efficiencies are not likely to be seriously exceeded since the necessary radiation and chimney losses are rarely below 12 to 14 per cent, and the problem at the present time is how close the average boiler-room efficiency, over a year, can be brought to the possible test efficiency.

With well-designed stations and careful operating, good coal and a reasonable load factor, the average yearly boiler-room efficiency has been maintained from 74 to 76 per cent in a number of the better plants. For a plant using around 300,000 tons of coal per year each additional per cent of efficiency means a saving of about 4,000 tons of fuel per year, or $20,000 at the present New York price of coal. Very few plants are provided with instruments for obtaining these facts from day to day, but the yearly use of coal is obtainable with sufficient accuracy from the coal bills or railroad weights, and all plants can afford water meters on the feed-water lines, although few have them. We may say that the poorer plants show a yearly boiler-room efficiency running from 50 to 65 per cent, and the better plants an efficiency from 65 to 75 per cent, beyond which it is extremely difficult to go on account of banking losses, combustible in the ash, excess air and cleaning losses.

Poor coal is responsible for large efficiency losses. The accompanying table, showing the effect of increasing percentages of ash in the coal on boiler efficiency, has been prepared from averages of a large number of tests on anthracite, bituminous and Western coals. These averages vary but show as a general rule that 20 per cent of ash content cuts down the efficiency 15 to 20 per cent; 40 per cent of ash reduces the efficiency by about 70 per cent, and with 50 per cent of ash it is practically impossible to maintain combustion, to say nothing of evaporating water or making steam. Iron oxide, with or without sulphur, accentuates this condition by producing a fusible ash which slags the grates and chokes the draft. The presence of combined water in most of the Western coals and lignites reduces the efficiency in a marked degree, but not to such extent as the presence of ash. Combustion is possible at a greatly reduced efficiency under exceptional conditions, even with as high as 50 per cent of water.

*Abstract by the *Electrical World* of a paper presented before the Association of Edison Illuminating Companies, New London, Conn., Sept. 15 to 18.

ADVANTAGE IN PULVERIZED FUEL.

Apparently the main advantage in the use of pulverized fuel is the fact that the surface of the solid particles of fuel has been augmented more than 200 times, so that ignition and combustion are nearly instantaneous and the mixture of air and combustible is much more nearly perfect, very little excess air being needed. The chief difficulty is in the feeding devices and so proportioning the combustion chamber and air inlet that the mixture is complete. Sufficient heat must be present at the ignition point to ignite every particle, and this temperature varies from about 600 deg. Fahr. with high volatile coals to 1,000 deg. to 1,200 deg. Fahr. for anthracite.

AVERAGE LOSS IN EFFICIENCY DUE TO ASH IN COAL

Per Cent of Ash	Loss of Efficiency: Anthracite Coal	Bituminous Coal	Western Coal
10	12	10	6
20	23	20	18
30	45	40	32
40	70	75	98
50	100	100	...

When these precautions are taken and the air is preheated, furnace temperatures up to 3,000 deg. Fahr. are easy of attainment, smokeless combustion is assured, and practically all the combustible is consumed. The combustion chamber must be proportioned for the maximum condition, in which case the efficiency will be nearly constant over a wide range.

Most of the ash will be deposited in the combustion chamber as dust with refractory ash or as slag if its fusing point is low. Apparently there is very little loss of efficiency with an increase of the ash content, as tests with high-ash coals show the same efficiency as with low-ash content. A properly designed combustion chamber limiting the gas velocities in the neighborhood of the firebrick surfaces will, it is claimed, overcome the excessive cutting and slagging of the brickwork so prevalent in all of the earlier experiments, and this proceeding will greatly diminish the amount of ash and slag particles carried into the tube banks and uptakes.

There remains the fact that the coal must be pulverized and therefore must be freed from moisture. Combined water to the extent of 5 to 7 per cent is not serious, but free water over 1 per cent usually makes trouble in the pulverizing and handling. Outside of radiation and stock losses and the loss from excess air, this is the only loss large enough to be troublesome.

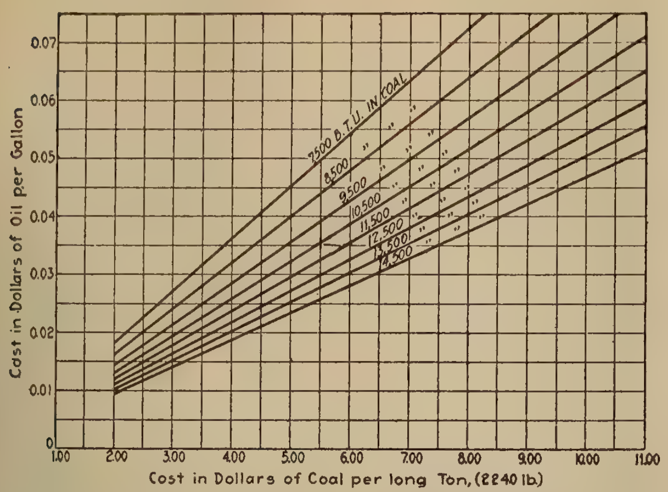
The advantages incident to a powdered-fuel installation may now be summed up:

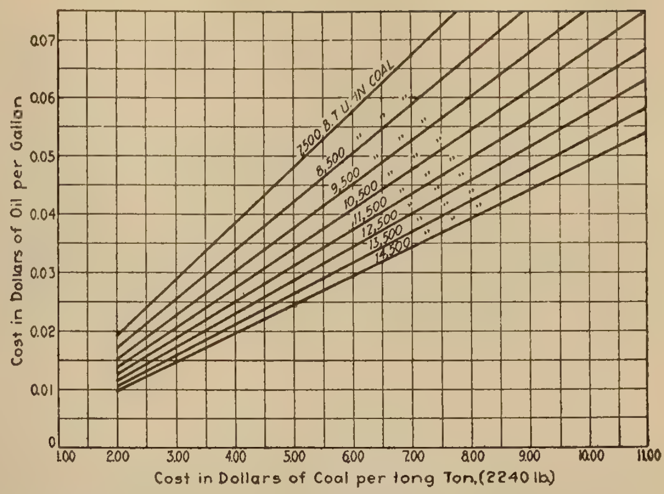
1. Ability to use all classes of coal with equal (or nearly equal) efficiency.
2. Reasonably smokeless combustion.
3. Absence of loss of combustible in the ash.

Against these may be placed these disadvantages:

1. The cost of drying and pulverizing the fuel.
2. Higher and possibly irregular temperatures with attendant disintegration of the firebrick furnace lining.

Where good coal is used and yearly station boiler efficiencies of from 74 to 76 per cent are obtainable, it may be possible to increase the yearly efficiency by 3 per cent. With a 65 per cent yearly efficiency at least 10 per cent better results should be obtained. Where cheaper grades of coal are available even more considerable savings are possible.





FIGS. 1 AND 2—COMPARATIVE COSTS OF COAL AND OIL IN HEAT EQUIVALENTS

Fig. 1 assumes coal burned at 70 per cent efficiency and oil at 74 per cent efficiency: 18,500 B.t.u. per pound in oil and that oil of 18 Baumé = 7.877 lb. per gallon. Fig. 2 assumes coal burned at 70 per cent efficiency and oil at 77 per cent efficiency; other assumptions the same. Saving of labor and in banking fires is not included.

This 3 per cent, or 60,000 a year, under our former supposition, will be offset by the cost of drying and pulverizing 288,000 tons of coal per year, which for no saving would mean 21 cents per ton as the cost of pulverizing. Where the yearly efficiency is 65 per cent and a 10 per cent saving could be made, 75 cents could be paid for pulverizing. For a plant using 1,000 tons per day the cost of pulverizing could not be far from 40 per cent per ton, leaving a net saving of over $80,000 per year. In general the pulverizing cost runs from 40 cents to 50 cents for the largest plants up to $1.50 or higher in small installations.

It will be readily seen that the poorer the plant in design and operating practice, the larger will be the savings from the use of pulverized coal as fuel, given the same coal conditions.

A late paper gives a list of powdered-coal installations for the generation of steam—eighteen in all; installed boiler horse-power, 24,000; average size, 1,333 h-p.; largest installation, Puget Sound Light & Power Company, 10 B. & W. boilers, 4,100 h-p.; next largest Milwaukee Electric Railway & Light Company, five 468 h-p. Edge Moor boilers, 2,340 h-p. These are the only central-station installations listed. Another company lists six installations of which one is under construction. The total boiler horse-power in this case is 22,000. The largest plant will be the River Rouge plant of the Ford Motor Company at Detroit, where four 2,645-horse-power Ladd boilers are being installed. Besides these there are numerous small installations not listed.

It was only a few years ago that oil as fuel began to be used in a few locations where coal freights were high and oil freights low. The newer developments of the Mexican fields and the steadily increasing price of coal now bring this subject to our attention.

The coal production in the United States is not far from 600,000,000 tons per year, of which about 40,000,000 tons is used in the making of steam by central stations for the generation of electric power.

The figures for oil production, including Mexico, are about 400,000,000 barrels, of which a little less than half may be available for power purposes, including gas-engine fuels. Excluding the portion used for marine purposes, possibly 40,000,000 barrels, mostly topped oil, will be available for steam purposes at a reasonable price. This would correspond roughly to 10,000,000 tons of coal. About 10,000,000 barrels of fuel oil per year are used for central-station purpose today.

Most authorities assume that oil firing will give a boiler efficiency 10 per cent better than coal firing. Indeed, long run efficiencies of 80 per cent have been reported and test efficiency of over 82 per cent is common. Taking oil as having a heating value of 18,500 B.t.u. per pound, and a coal a value of 13,500 B.t.u. per pound, oil at 3 cents per gallon is equivalent to $5.65 coal. If only 4 per cent better efficiency is maintained, then 3-cent oil is equivalent to $5.90 coal. I have not considered the saving in labor, banking coal, ash handling, etc.

On this basis I have calculated the two charts in Fig. 1 and 2, which show the corresponding price of oil and coal. No difficulty need be apprehended in the change-over. Indeed, oil burning is frequently successful in old-fashioned low settings; the grates are covered with firebrick and the burner inserted in the firedoor. It is generally agreed that steam atomizing is more efficient than air atomizing or mechanical atomizing, but mechanical atomizing is largely used in marine work and in the smaller land installations. With steam atomizing the use of steam may be as large as 15 per cent of the boiler evaporation, but the best results are obtained when careful regulation restricts the use of steam to 1½ to 2½ per cent of the boiler output.

The type of burner, while important, has much less effect on the efficiency of combustion than the size and design of the combustion space and the arrangements for the introducing and regulating of the air necessary for combustion.

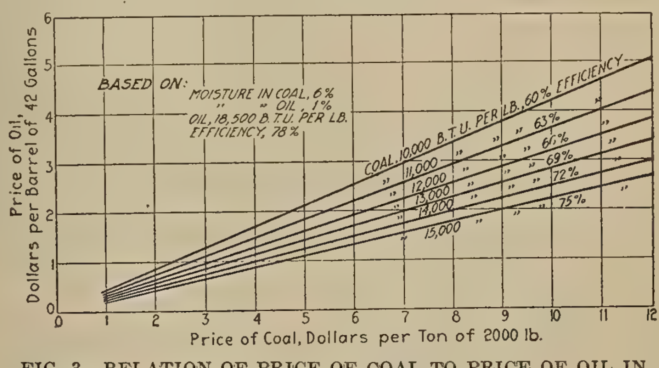


FIG. 3—RELATION OF PRICE OF COAL TO PRICE OF OIL IN HEAT EQUIVALENTS

Oil storage and firing devices, while costly in a new installation, will cost less than coal bunkers, coal-handling machinery, stokers and forced-draft apparatus. The cost of operating the oil storage and feeding devices depends in a large measure on the mean annual temperature since fuel oil is extremely viscous and must be warmed sufficiently to be pumped and then preheated to secure good ignition before injection into the furnace. As the flash point of fuel oil is always above 150 deg. Fahr., the item of fire risk is very low, all of the so-called "wild hydrocarbons" having been removed in the topping process.

We may now state the advantages of oil firing:

1. An almost perfect control of firing and combustion conditions, insuring high and maintained boiler efficiency over a wide range.

2. Extreme flexibility.

3. Low labor cost both in the boiler room and bunkers.

4. Stability of costs due to the conditions of production and the increasing demand for the products of the topping process.

The disadvantages are:

1. Limited applicability to favorable localities.

2. The relatively high cost of installation, which does not decrease with size of plant.

LIQUID OXYGEN AS AN EXPLOSIVE.*

By ALBERT G. WOLF.

FOR many years it has been known that liquid air or liquid oxygen mixed with some highly carbonaceous substance makes a powerful explosive when detonated. During the war some experimental work was done in America along this line, but, owing to the difficulty in handling, in part, and largely to insufficient pressure by "Mother Necessity," no great measure of success was attained, and the method was dropped as being of no commercial or practical value. In Germany, however, conditions were entirely different. There, according to the publications of the German Oxhydric Joint Stock Co., the method was brought to a fairly high degree of perfection.

The liquid oxygen, or, as used, a liquid consisting of 98 per cent oxygen, is made from air. The air is first washed free from carbon dioxide. Then it is liquefied by the expansion process, multi-stage compressors and ammonia refrigerating machines being used. After making the liquid air, the oxygen content is raised by taking advantage of the lower boiling point of liquid nitrogen. The liquid nitrogen, evaporating first, leaves a higher percentage of oxygen in the liquid residue, and by carrying out this step in a specially designed apparatus in which advantage can be taken of the extremely low temperature created by the evaporation of the liquid nitrogen, a fairly high degree of efficiency is obtained.

In order to form an explosive mixture, a highly carbonaceous material with the power of absorbing liquid is necessary in addition to the liquid oxygen. This material should preferably be shaped in the form of dynamite sticks for convenience in handling and loading. It is claimed that best results are obtained from cartridges made of cork charcoal and a binder of paraffin. The binder may also be any one of the lighter petroleum products. Kieselguhr (diatomaceous earth) with a binder of paraffin may also be used. In that case the paraffin alone furnishes the carbon, and the explosive is not as powerful as when the charcoal cartridge is used. A good ratio is said to be 60 parts of kieselguhr to 40 parts of binder.

In using this explosive, the liquid oxygen must be carried to the working place in tightly closed thermos bottles, in order to avoid loss by evaporation. The liquid oxygen is then poured out into double-walled vessels, and the cartridges are placed in the liquid to soak. The cartridges must be capable of absorbing sufficient excess of oxygen to insure the presence at the time of detonating of enough to burn all the carbon to carbon dioxide and all the hydrogen to water. Otherwise the deadly carbon monoxide gas will be formed on exploding the charge.

The cartridges are saturated when they sink. They are then hastily removed from the bath, placed in the drill holes, fitted with electric blasting caps, tamping placed before them, and exploded. Not much time must elapse between the removal of the cartridges from the bath and the detonation, the permissible time varying from three to fifteen minutes, depending on the nature and size of the cartridge, because of the rapid evaporation of the liquid oxygen. For this same reason the diameter of the cartridge should not be less than 30 mm. The drill holes should be slightly larger to allow the oxygen vapor to escape while loading, otherwise the cartridges might be prematurely pushed out of the hole.

Though electric firing gives the best results, it is possible to use fuse and cap, or fuse alone. With the fuse, however, there is the danger of prematurely igniting the oxygen vapor and of getting an incomplete combustion. Fuse, of course, should not be used where there is the possibility of fire damp being present.

Experiments have shown, according to the claims of German manufacturers, that to get the same force of explosion, the relative weights of various explosives must be used:

Cork charcoal, paraffin and liquid oxygen	58
Kieselguhr, paraffin and liquid oxygen	115
Blasting gelatin	86.2

The advantages claimed for this method of blasting are primarily economy, safety, and greater strength of explosion. Economy is claimed because each mine can operate its own little liquid oxygen plant for not much more than the cost of operating a compressor plant, making it necessary to buy only the cartridges of carbon. There is safety in handling and storage because the separate ingredients are not explosive. There is absolutely no danger from misfires, because in fifteen to thirty minutes all the liquid oxygen in a drill hole evaporates; and, it is claimed, with the lower-strength cartridges, there is no danger of igniting fire damp. There are also the advantages that low temperature has no effect on the explosive, and, where proper precautions are observed, no poisonous gases are formed.

To the average mine operator or miner, the disadvantages of this method far outweigh the advantages. There is the trouble of carrying the liquid oxygen containers and immersion vessels, in addition to the cartridges, to and from the working faces, the loss of a good percentage of these vessels and the resulting cost, the loss of a large percentage of the liquid oxygen, and the operation of the liquid-oxygen plant. Then there is the danger from hasty and improper immersion, with its resulting loss in efficiency of the explosive and the formation of poisonous gas in the mine. In large stopes, the complication that would arise from the use of liquid oxygen would be almost insurmountable.

*Reprinted from the *Engineering and Mining Journal*, Feb. 4, 1920.

MAKING THE ROOF SAVE HEAT.

Two of the main functions of a good roof are the keeping in of heat in the winter and the keeping out of heat in the summer, the former being by far the most important, in this climate, at any rate. It is usually supposed that this power of keeping heat in or out as the case may be is dependent upon the quality of the roofing, as a good conductor or a bad conductor of heat. Some highly interesting studies made by Mr. W. M. Thornton of the National Physical Laboratory in England, with regard to roof materials, prove, however, that the brightness or dullness of the roof is also an important factor. Mr. Thornton found, in fact, that loss of heat through the roof depended more upon the nature of the surface and the degree in which it radiates heat than on the conductibility of the materials. The same grade of galvanized iron roofing which is an excellent heat insulator when polished loses 50 per cent more heat when it is blackened inside and more than five times as much when it is blackened on both surfaces.

One of the best of roofing materials proved to be pine covered with tar paper; tiles are also excellent, but are, of course, much heavier, as well as more expensive. Fibrocement was likewise found to be very good, and is improved by painting with aluminum. A specially admirable roof when one wishes to have a house covering which is both light and warm is one made of corrugated fibro-cement covered on the underside with a continuous layer of tar paper, the cushion of air enclosed between the two layers adding materially to the warmth of the roof.

CALCIUM MOLYBDATE

FERRO-MOLYBDENUM

Qualities of the Molybdenum Steels*

New Alloy That Came Into Use, During the War, for Aircraft Crankshafts, Gun Shields, and Similar Purposes

IN the course of the war there were introduced into practical use a series of new alloy steels which bid fair to become of great value to the automotive industry. Reference is to molybdenum steels, which are generally of the nature of ternary or quarternary alloys. During the war molybdenum steel was used for the fighting turrets of tanks, for gun shields, helmets, aircraft engine crankshafts and connecting rods, and for other parts requiring great strength combined with low weight.

Among the chief advantages claimed for alloy steels containing molybdenum are that it does not require the same care in heat treatment as other steels, as practically the same physical properties are obtained for a range of more than 200 degrees Fahrenheit in the quenching temperature. Molybdenum improves the static test results of various kinds of alloy steel to which it is added, such as chrome steel, chrome vanadium steel, etc. Moreover, molybdenum steel is said to be easier to machine than other alloy steels and the saving in machining cost easily pays for the cost of the alloying element, it is claimed.

A PILE OF MOLYBDENUM CONCENTRATES

THE ELEMENT MOLYBDENUM.

Molybdenum, one of the metallic elements, has been known for about 150 years. It derives its name from the word molybdæna, by which most minerals resembling lead in appearance were known in the 18th century. It is produced chiefly from the sulphite molybdenite ($Mo\ S_2$) which is a mineral very similar in appearance to graphite. Molybdenite and other molybdenum-bearing ores are widely distributed throughout the world.

The metal molybdenum resembles platinum in general appearance, although it is darker and possesses a peculiar lustre. Its atomic weight is 96; its specific gravity is 9; its specific heat 0.07, and it melts at about 4600 deg. F. Despite its very high melting point, it alloys readily with iron, the ferromolybdenum having a melting point of approximately 2650 deg. F. Metallic molybdenum exhibits a high degree of resistance to the corrosive action of most acids and chemicals.

ORE DEPOSITS IN COLORADO.

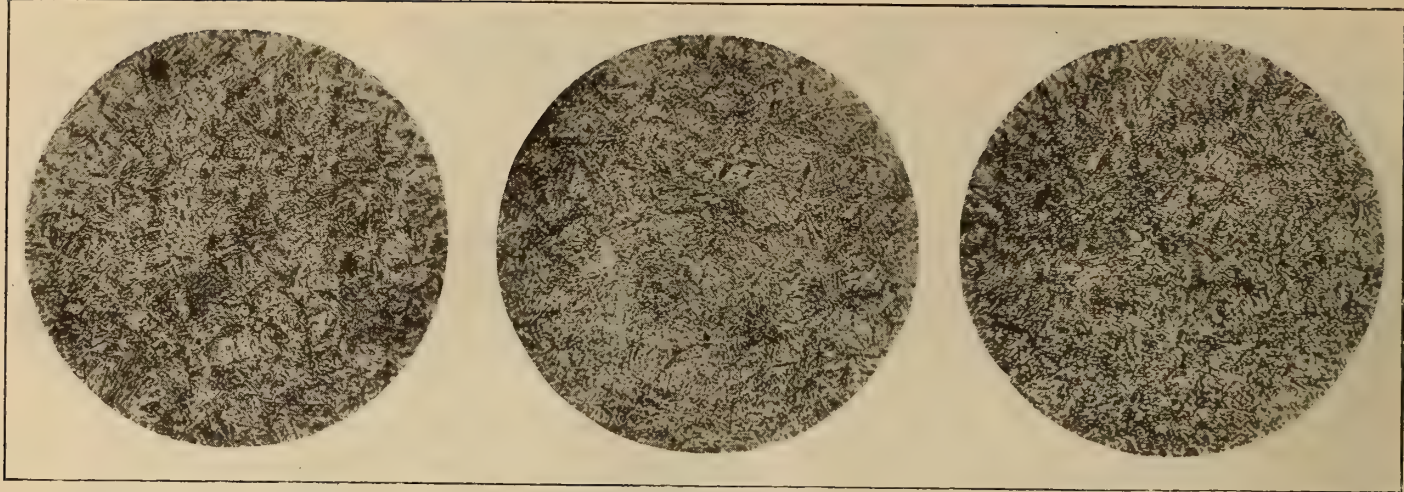
While its ores are widely distributed, up to a few years ago molybdenum was considered a semi-precious metal, no deposits of any great magnitude having been discovered. A few years ago a company acquired possession of a deposit of molybdenum sulphide at Climax, Col., northeast of Leadville. At that point an ore reserve has been developed which at present has a capacity of 1,000 tons a day, and it is claimed that the ore which has already been developed insures steady operation of the plant for more than thirty years. The entire ore body has not yet been developed.

The ore is broken, delivered to the mill by aerial tramway, ground and concentrated by oil flotation to form 60 to 70 per cent molybdenum sulphide. The concentrates are then converted into ferromolybdenum or calcium molybdate, in either of which forms the metal can be introduced into steel. The ferromolybdenum is produced in two grades, both containing from 50 to 60 per cent metallic molybdenum. The regular grade is guaranteed to contain a maximum of 2 per cent carbon, and the special grade, of 0.5 per cent. In the great majority of instances, the former can be used. The calcium molybdate contains about 42 per cent metallic molybdenum, the rest being lime. There is said to be no free carbon or sulphur in this compound.

INCREASES TOUGHNESS OF STEELS.

One of the claims made for molybdenum steel is in regard to toughness, and this claim is based on "reduction of area" figures obtained in physical tests. Molybdenum steels of any given elastic limit and elongation are characterized by an extraordinarily high reduction of area. Reduction of area is also said to be an index of machineability. For machine parts requiring a high elastic limit, the cheapest method of manufacture consists in finish-machining the parts directly from the heat-treated forging. This eliminates warping and scaling

*Reprinted from *Automotive Industries,* January 29, 1920.



DRAWN AT 350 DEG. F. DRAWN AT 700 DEG. F. DRAWN AT 1100 DEG. F.
TRANSVERSE SECTIONS OF TYPE I-A ALLOY MAGNIFIED 300 DIAMETERS

of semi-machined parts. Furthermore, material submitted to the machine shop is completed without the loss of time and the confusion resulting from intermediate heat treatments. All testing is finished before machine labor is expended upon parts which might have to be rejected later, such rejection involving the loss not only of material but also of labor and tools.

HIGH DRAWING TEMPERATURES.

One peculiarity of molybdenum steel is that it will acquire desirable physical properties when drawn at a comparatively high temperature. The physical changes accompanying the usual heat treatment are well known. When a piece of steel is heated beyond a certain critical temperature it undergoes a physical transformation. If it is allowed to cool slowly from the highest temperature reached, the process reverses itself and the material returns to its original state. On the other hand, if the steel is cooled rapidly, as by quenching, the physical changes which took place on heating, cannot reverse themselves, and the material then remains in a state of unstable equilibrium. When the quenched steel has been reheated or drawn, physical reactions, which were retarded by quenching are allowed to take place to an extent proportional to the reheating temperature, and the molecular instability induced by quenching is somewhat modified.

It results from the above that the higher the drawing temperature after quenching, the nearer the approach to a state of molecular equilibrium, and consequently the greater the resistance of the material to any subsequent molecular change. One form of molecular change in steel is that known as fatigue, which is the result of continued mechanical vibration. It is argued that the higher the drawing temperature for given physical properties, the greater the resistance to dynamic stress or to fatigue. Higher drawing temperatures mean ease in furnace regulation and manipulation, and, furthermore, the nearer the approach to the point of molecular equilibrium, the less sensitive is the steel to temperature variations. In other words, wider limits may be allowed in commercial heat treating practice. It need hardly be emphasized that the wider these limits the less chance there is for failure of the treatment and for the necessity of retreatment.

RELATED TO CHROMIUM.

In the periodic system of elements, molybdenum is classed as a member of the chrome family. In some respects its effect upon steel is similar to that of chromium. It has been found, however, that by combining these two alloying elements, properties can be developed in steel which are unobtainable by the use of any single element.

Accompanying this article are a number of photo micrographs which bring out the effect of different amounts of molybdenum on the structure of quenched and drawn chrome molybdenum steel. They also indicate the uniformity of the steel when drawn at different temperatures. All of the steels of which photo micrographs are shown were quenched in oil from 1600 deg. F., and drawn as indicated. Steels of two different specifications were made use of in producing these photo micrographs; all those bearing the number I contain 0.25 per cent of carbon, 0.48 per cent of manganese, 0.18 per cent of silicon, 0.95 per cent of chromium and 0.73 per cent of molybdenum, while all those bearing the number II contain 0.32 per cent of carbon, 0.49 per cent of manganese, 0.10 per cent of silicon, 0.90 per cent of chromium and 0.40 per cent of molybdenum.

CHROME-MOLYBDENUM STEEL.

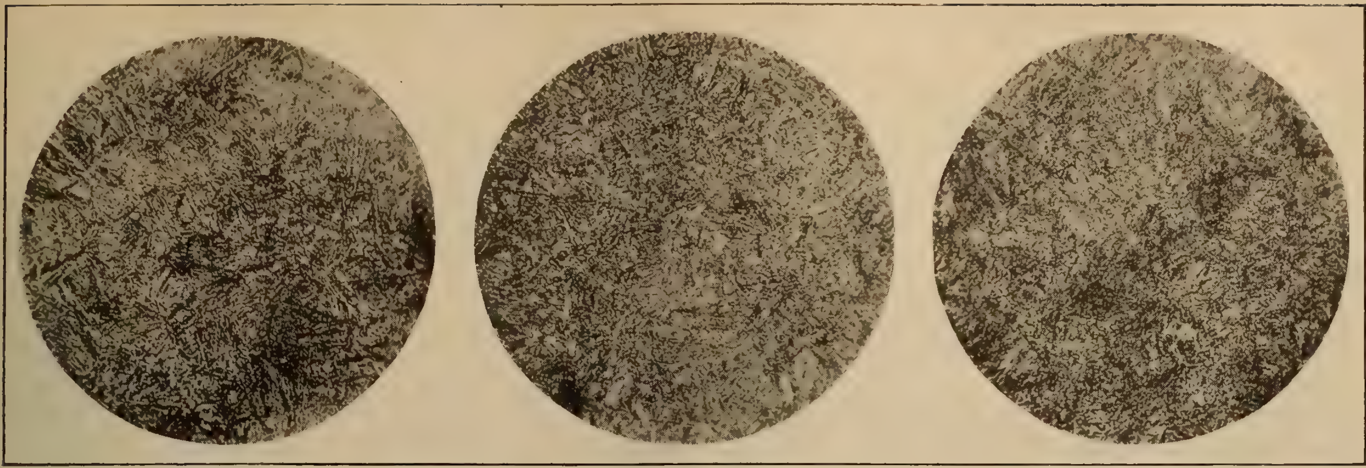
If chromium be added to a carbon steel or a nickel steel, and the steel subsequently be heat-treated, their elastic limit and tensile strength are increased (up to a certain point) with the quantity of chromium. However, it is impossible practically to take advantage of the high elastic limits resulting from the addition of a considerable amount of chromium, because it is accompanied by brittleness (as measured by low elongation and reduction of area). For regular commercial purposes the limit of chromium is in the neighborhood of 1 per cent, although for several purposes up to 1½ per cent of chromium is sometimes added. If steel with a normal per cent of chromium is taken and molybdenum is then added, the elastic limit is increased more than it would be by a further equal addition of chromium, and—what is of the greatest importance—the brittleness is decreased at the same time.

Thus a chrome carbon steel, containing 0.27 per cent carbon, 0.64 per cent manganese and 0.99 per cent chromium, when properly heat-treated, showed the following physical properties: Elastic limit, 130,000 pounds; tensile strength, 139,000 pounds; elongation, 16.5 per cent; reduction of area (1 in. round), 58 per cent. Upon the introduction of a moderate amount of molybdenum, so as to obtain a steel containing 0.26 per cent of carbon, 0.64 per cent of manganese, 0.77 per cent of chromium and 0.31 per cent of molybdenum, the following physical properties were obtained: Elastic limit, 143,000 pounds; tensile strength, 151,000 pounds; elongation, 18.5 per cent; reduction of area of 1 in. round specimen, 53 per cent.

While the results obtained from the chromium steel are of a high order, to obtain them in regular commercial practice requires very careful supervision of the heat treatment and of the chemical composition of the steel. It is claimed for molybdenum that it not only intensifies the effect of the chromium itself, but has an independent effect on those properties of the steel which are undesirably affected by the use of chromium alone.

CHROME NICKEL MOLYBDENUM STEEL.

The effect of adding molybdenum to chrome nickel steel is well brought out by the following analysis of a Liberty motor crankshaft. The chrome nickel steel originally used for this



DRAWN AT 700 DEG. F. DRAWN AT 1100 DEG. F. DRAWN AT 1300 DEG. F.

TRANSVERSE SECTIONS OF TYPE II-A ALLOY MAGNIFIED 300 DIAMETERS

crankshaft contained from 0.35 to 0.45 per cent of carbon, 0.50 to 0.80 per cent of manganese, 0.10 to 0.20 per cent of silicon, 0.70 to 0.90 per cent of chromium and 1.75 to 2.75 per cent of nickel. This material showed an elastic limit of 129,760 pounds, a tensile strength of 144,460 pounds. an elongation of 17.2 per cent, a reduction of area of 53.7 per cent, an Izod impact value of 46 ft.-lb., and a Brinell hardness of 307.

Another grade of chrome nickel steel used in connection with aircraft production during the war had the following chemical composition: 0.28 to 0.37 per cent of carbon, 0.30 to 0.70 per cent of manganese, 0.10 to 0.25 per cent of silicon, 0.65 to 1.36 per cent of chromium and 3.04 to 3.50 per cent of nickel. This showed the following physical properties: Elastic limit, 167,000 pounds; tensile strength, 135,200 pounds; elongation, 19.6 per cent; reduction of area, 51.7 per cent; Izod impact value, 61 ft.-lb.; Brinell hardness, 370.

Liberty aircraft engine crankshafts were made from chrome nickel molybdenum steel made by the United Alloy Steel Corporation of Canton, Ohio. This steel contained from 0.236 to 0.305 per cent of carbon, 0.50 to 0.69 per cent of manganese, 0.09 to 0.15 per cent of silicon, 0.74 to 0.98 per cent of chromium, 2.85 to 3.05 per cent of nickel and 0.32 to 0.54 per cent of molybdenum. This steel tested as follows: Elastic limit, 130,000 pounds; tensile strength, 142,000 pounds; elongation, 20.5 per cent; reduction of area, 65 per cent; Izod impact value, 67 ft.-lb.; Brinell hardness, 303.

STEEL SUITED FOR AUTOMOBILE PARTS.

For such automobile parts as crankshafts, connecting rods, steering knuckles, steering levers, front axles, etc., grade MO-2 steel is frequently used. Tests on specimens from approximately 4,000 finished crankshafts made from this grade, at the plant of a large American automobile manufacturer, showed the following average compositions and physical properties: Carbon, 0.25 to 0.33 per cent; manganese, 0.71 to 0.76 per cent; chromium, 0.45 to 1.04 per cent; silicon, 0.11 to 0.22 per cent; molybdenum, 0.32 to 0.46 per cent. The physical properties averaged as follows: Elastic limit, 131,700 pounds; tensile strength, 149,900 pounds; elongation, 17.7 per cent; reduction of area, 61.8 per cent; Brinell hardness, 304. Chrome vanadium steels used for crankshafts under the same operating and test conditions at the same plant showed approximately the same elongation, reduction of area and Brinell hardness, but the elastic limit averaged only 113,000 pounds, and the tensile strength 127,600 pounds. This same steel is used for cold drawn automobile axle shafts, and in this form shows an elastic limit of 145,000 to 156,000 pounds per square inch, and a tensile strength of 164,000 to 171,000 pounds per square inch. As an indication of the extraordinary toughness of molybdenum steel, the following results from a class steel containing from 0.75 to 1 per cent of molybdenum are interesting. The test was made on a 1⅛-inch round specimen 24 inches long. It showed a fiber strength at the elastic limit of 50,100 pounds, and a fiber stress at the breaking point of 107,000 pounds. The twist degree per inch, before failure, was 258.

These results were obtained from test pieces taken from the finished crankshaft, and they should be read in the light of the knowledge that it is possible to draw the steel at from 1150 to 1200 deg. F. The high drawing temperature removes quenching and forging strains, thus eliminating the need for straightening operations during machining. It is stated that the shafts machined exceptionally well.

NICKEL-MOLYBDENUM STEELS.

The addition of molybdenum to nickel steel containing no chromium results in markedly increasing the elastic limit and the toughness and ductility for a given elastic limit, as measured by a reduction of area and elongation. This effect is particularly pronounced when the steel is drawn at higher temperature. Nickel molybdenum steels can be readily machined, and can be heat-treated without detriment to their physical properties within a wide temperature range; they are exceptionally homogeneous and free from fiber and flakes. As an instance of the homogeneity of the steel and its freedom from defects, it is mentioned that in the manufacture of the Renault baby tanks, over 99½ per cent of the nickel molybdenum steel parts passed all stages, including ballistic tests, while 76 per cent was the maximum in the case of the straight nickel steel.

It is claimed for molybdenum steels that they are less liable to warp in the course of manufacture, owing to the depth-hardening effect of molybdenum, which, among other things, permits the quenching of irregular sections with a minimum of warping. This peculiarity of the steel is of considerable commercial value in connection with oil-hardened parts, as straightening operations during manufacture are eliminated.

The following two tables show that molybdenum steel can be heat-treated at widely varying temperatures without detriment to its physical properties:

TENSILE TEST OF CHROME-MOLYBDENUM STEEL, MO-2

Analysis Range

Carbon	Manganese	Chromium	Silicon	Molybdenum
.23 to .30	.50 to .80	.80 to 1.10	.10 to .20	.25 to .40

Physical Properties

(1¼ inch round)

Water Quench	Elastic Limit	Tensile Strength	Elongation Per Cent	Red. of Area Per Cent
1500° F.	149,600	162,900	16.0	57.2
1550° F.	151,000	163,400	16.5	57.3
1600° F.	148,800	163,600	17.0	57.3
1650° F.	148,500	161,400	16.5	58.9
1700° F.	149,500	162,400	16.5	56.8

All drawn at 1000° F.

TENSILE TEST OF CHROME-NICKEL MOLYBDENUM STEEL, LM

Analysis Range

Carbon	Manganese	Nickel	Chromium	Molybdenum
.25 to .35	.50 to .80	2.75 to 3.25	.70 to 1.00	.30 to .50

Physical Properties

(1 inch round)

Oil Quench	Elastic Limit	Tensile Strength	Elongation Per Cent	Red. of Area Per Cent
1400° F.	175,200	185,000	16.0	52.5
1450° F.	179,300	187,400	15.5	51.5
1500° F.	171,200	182,700	16.5	55.1
1550° F.	174,200	185,100	16.0	52.8
1600° F.	172,700	183,500	15.0	51.7

All drawn at 1000° F.

It will be seen from these tables that in spite of the wide range in drawing temperatures, there was only a slight variation in the physical properties.

What is referred to as the depth-hardening effect of molybdenum is illustrated by Brinell hardness readings taken along diagonal lines of 3½-inch square sections of molybdenum and chrome vanadium steel respectively. The maximum hardness in each case was 293, while the minimum hardness, at the center of the section was 262 in the case of chrome molybdenum steel, and 235 in the case of the chrome vanadium steel.

FIVE TYPES OF MOLYBDENUM STEEL.

Molybdenum steels are made in five types, as follows:

Type MO, chrome molybdenum.
Type MS, chrome molybdenum, higher carbon.
Type LM, chrome nickel molybdenum.
Type NM, nickel molybdenum.
Type VM, chrome-vanadium molybdenum.

The type MO is made in three molybdenum ranges, as follows: Class A, 0.25-0.40 per cent molybdenum; class B, 0.50-0.75 per cent molybdenum; class C, 0.75-1.00 per cent molybdenum. It has been found, however, that the class A meets practically all commercial requirements and is usually specified.

The MS type of chrome molybdenum steel is used for chassis springs and for heavy gears. The carbon content is made as low as 0.35 per cent for forgings and as high as 0.6 per cent for rivet sets, etc. Besides, the steel contains 0.60-0.90 per cent of manganese, 0.10-0.20 of silicon, 0.80 to 1.10 per cent of chromium and 0.25 to 0.40 per cent of molybdenum. Physical properties obtained in the spring steel are as follows: Elastic limit, 180,000-210,000 pounds; tensile strength, 200,000-230,000 pounds; elongation, 12 to 15 per cent; reduction of area, 37 to 45 per cent.

ADDITION OF MOLYBDENUM TO STEEL.

There has been an impression, based upon past practice, that molybdenum, when introduced into steel, will volatilize or oxidize out of the bath. This is denied by molybdenum producers who assert that the metal can be introduced into steel as easily as nickel, and with recoveries practically as good. Molybdenum, in the form of a ferro-alloy, may be introduced into the steel by any of the customary methods. Recent developments have shown that it may also be introduced in the form of calcium molybdate. With ferro-molybdenum, the alloy may be introduced in the bath just after the charge becomes plastic, and a little before the melt becomes level, when it may be thrown in, casks and all. It should not be added with the charge because of possible loss on the furnace bottom. It may also be added just after the final additions of ferro-manganese and ferro-chrome, that is, a few minutes before the furnace is tapped.

Instead of adding the alloy to the bath, it may be added in the ladle, in which case it is advisable first to melt it, and then pour it into the molten stream after the furnace is tapped. This latter method was the first one to be employed during the war, but it was later replaced by the previously described method. When calcium molybdate is used, it is added in the early stages of the heat, preferably a little before the melt becomes level. Whatever the type of furnace, it is well to remember that the molybdate must come in direct contact with the molten iron, and must therefore be added (in the basic furnace) before the lime begins to come up. Shipped in sheet iron drums or in sacks, the molybdate is added, containers and all.

Researches at High Temperatures and Pressures*

Investigation Into the Internal Conditions of the Earth

By Sir Charles A. Parsons, K.C.B., F.R.S.

JUST ten years ago in this room Sir Richard Threlfall discussed the effects of temperature and pressure on various substances, and commenced by referring to a suggestion I made in 1904 to sink a bore-hole twelve miles deep in the earth with the object of exploring the region beneath us, about which so little is known. Last summer at Bournemouth I ventured again to direct attention to the desirability of such an exploration in the interests of science generally, and to the possibility that it might ultimately lead to some developments of practical importance and utility.

Ten years ago no experiments had been made on the behavior of rocks under the conditions existing at great depths below the surface of the ground; but, prompted by my suggestion in 1904, and after some subsequent correspondence in regard to the possibility of the rock crushing in and closing the shaft, Prof. Frank D. Adams, of McGill University, Montreal, commenced experiments on the strength of rocks to resist the closing up of cavities under the conditions prevailing at great depths below the surface. He published the account of these experiments in the *Journal of Geology* for February, 1912.

Adam's method was to place a block of granite or limestone in a tightly fitting cylinder of nickel-steel, which was shrunk lightly around the block to ensure perfect fitting and support; hard steel rams actuated by a hydraulic press were arranged to exert a known pressure against the ends of the block. Two small holes were previously drilled in the specimen, one axial in the center and one traverse, the diameter of the holes being 0.05 in., or one-tenth the diameter of the specimen. The temperature of the container and specimen was maintained at any desired point up to the softening point of steel. In some experiments no heat was applied, while in others the temperature was raised to that estimated to exist at the depth below the surface of the earth corresponding to this pressure.

When no heat was applied the holes in the granite showed no alteration under a pressure equivalent to thirty miles deep, and in the case of limestone the specimen supported one-half of this pressure without alteration. Adams then raised the temperature of the container and specimen. When granite was heated to 550°C., a temperature corresponding to eleven miles below the surface, it stood a pressure equivalent to fifteen miles, and might have stood more but that the container became weakened by the heat. Limestone begins to decompose at a temperature of 450°C., but even at this temperature it withstood a pressure corresponding to ten miles.

*Discourse delivered at the Royal Institution on Friday, January 23. Reprinted from *Nature* Feb. 19 and 26, 1920.

Adams concludes that small cavities in granite will not close in under the conditions of pressure and temperature at eleven miles below the surface, however long a time is allowed to lapse, and that the cavities may persist to much greater depths, but the softening of the steel of the container precluded the carrying of his experiments to still higher temperatures and pressures.

So far as they go, these experiments are reassuring as to the permanence and safety of a pit shaft twelve miles deep sunk through granite, but it would be more satisfactory to experiment on a larger specimen than one only ½ in. in diameter as used by Adams and to heat the specimen electrically when submerged in graphite while keeping the container cold, the temperature being indicated by a thermo-couple in the specimen. This could be carried out in a nickel-steel container like that shown in Fig. 2.

In this connection P. W. Bridgeman in 1911 submerged a sealed glass tube containing a cavity under an external hydrostatic pressure of 24,000 atmospheres (corresponding to a depth in the earth of fifty-six miles) for three hours, and the cavity showed no change in size or form. It, however, appears that temperature will probably place a limit to the depth that could be reached before the closing in of the shaft commences to occur, for Judd, Milne, and Mallet agree in the view that the deepest origin of earthquakes is between thirty and fifty miles. This would seem to indicate that at greater depths than thirty miles the temperature and pressure are such that changes of form take place by plastic deformation, and not by sudden slips or the formation of faults, which are the chief cause of earthquakes. Again, Oldham states that beyond twenty miles deep seismic waves which are transmitted by compression and distortional vibrations change in character in this respect that though the compressional waves are only slightly affected in velocity, on the other hand the distortional waves are reduced to one-half their velocity. This would seem to imply that the modulus of elasticity in shear has, at twenty miles depth, owing to the rise of temperature, fallen to one-half, and it seems probable that the rock also is weakening in its resistance to shear; in fact, that the rock is becoming more plastic, and that cavities would probably close up at twenty miles below the surface.

The greatest depth to which a shaft has as yet been sunk is only about 1 1/5 miles. The deepest single-stage shaft on the Rand is that of the Hercules East Rand Proprietary Mine. It is 4,500 ft. vertically, and rectangular in section. The deepest shaft in the world is that of Morro Velho, Brazil. The bottom is 6,400 ft. vertically below the surface, and it has been sunk, and is worked, in stages, two of which are about 1,200 ft. vertical. The deepest shaft designed on the Rand is by the City Deep Co. It is 7,000 ft. vertically, is circular of 20 ft. diameter, and is to be worked in two stages of 3,500 ft. each. The most rapid sinking record was made at the Crown Mines No. 15 Shaft, where 310 ft. were sunk in a month; the shaft is circular, and of 20 ft. in diameter.

There are several interesting departures from ordinary mining practice necessary. The haulage is arranged in stages of about half a mile, principally in order to economize the weight of rope and also the power for winding. In countries where the atmosphere is dry the sides of the shaft are cooled by sprinkling water upon them, which by evaporation cools the rock. It is, however, possible to augment the effect by artificially drying and cooling the air before passing it down the mine.

When still greater depths of shaft are in contemplation further methods of cooling in addition to these would probably be found necessary; for instance, the carrying of the heat upwards by means of brine circulated in a closed ring formed of steel pipes with a rising and descending column. Though the columns might be carried the whole depth of twelve miles, the hydraulic pressure at the bottom would be about 12 tons per square inch, and entail very costly pipes of great strength to resist the pressure. A cheaper plan would be to work in stages, each ring covering a stage of from two to three miles of the shaft, the heat being transferred from the top of one brine ring to the bottom of the ring above by surface-heat exchangers and refrigerating machinery to neutralize the heat drop on transfer. These may be called heat pumps, and would be driven electrically.

As the depth of the shaft increases, the pressure of the air upon the miners will be about doubled for every three miles, but what is more serious is the increase in temperature of the air itself caused by the adiabatic compression due to gravity, by which it will be raised about 100°F. For these reasons it will be necessary to place airtight partitions across the shaft at every mile or two, and to carry on the ventilation through these by means of a pump to deliver the foul air upwards and an expander to allow the fresh air to descend. These two machines would be linked together, and the difference in their power supplied by an electric motor. (This method has been often used with water, and is equally applicable to air.)

At each partition heat exchangers and refrigerating machinery similar to those used for the brine would be placed. Another and preferable plan would be to place numerous heat exchangers between the ascending columns of air to transfer heat from one to the other. The air would, in this case, not itself act as a conveyor of heat to the surface, for which the brine columns would be depended upon, but it would enable airlocks every three miles to suffice. A further alternative and very simple method would be to convey liquid air from the surface, and allow it to escape at the part of the shaft requiring cooling. It would ensure good ventilation.

When sinking the deeper portions of the shaft, shields would probably be necessary to protect the miners from the splintering of the rock which is caused by the intense compressive stress, which splits off scales from the surface, sometimes with considerable violence.

In 1904 the estimate of the time required to sink twelve miles was eighty years, and was based on the records of that time. With improved machinery and methods the records have been so much lowered that an estimate of thirty years seems now to be reasonable.

Threlfall traced the gradual evolution of the theory of the effects of temperature and pressure on the allotropic forms of various substances. He described his apparatus and experiments designed to melt graphite under high pressure, his inference then being that under pressures up to 100 tons per square inch carbon does not follow the same law as many other substances and does not crystalize as diamond on cooling.

An interesting discovery was made by Bridgeman in 1911 when studying the compressibility of mercury. He found that it had a remarkable power of penterating steel containers, a power not possessed by oil or water, which caused them to burst at much lower pressures than when they were charged with oil or water. The phenomenon he attributed to the act that mercury has the power of dissolving small percentages of iron, and will amalgamate with it when the surfaces are absolutely free from oxide.

In 1912 Bridgeman published his remarkable researches on water under pressures up to 20,000 atmospheres. He found that there are four allotropic forms of ice besides ordinary ice, which are found under various conditions of pressure and temperature with determinate regions of stability. All these forms except ordinary ice are more dense than water; one is remarkable as existing from a temperature of -18°C. under a pressure of 4500 atmospheres up to a temperature of 67° C. under a pressure of 20,000 atmospheres.

Recently a pressure of from 200 to 1,000 atmospheres at a temperature between 50° and 700° C. has been applied to compel hydrogen to combine with nitrogen to form ammonia on a great commercial scale, a catalyst being necessary to promote the combination and to establish the equilibrium between the gases and their product. This action is reversible as

regards temperature and pressure. On the other hand, iron just molten is an energetic catalyst in the transformation of diamond into graphite, but, contrary to expectations, as we shall see, no amount of pressure that has yet been applied appears to have caused a reversal of this action.

More than thirty years ago, having suitable apparatus at hand, I made a few experiments to try the effect of high pressures and temperatures on carbon, compounds of carbon, and some other substances.

The apparatus consisted of an 80-ton press, under which suitable containers were placed, and a turbo-generator of 24 kilowatts output at 80 volts provided the current. It had been discovered by Cheesborough that the carbon filaments or incandescent lamps became very hard and resilient when heated in a hydrocarbon atmosphere of about 4 mm. absolute pressure, and I was anxious to try what would be the result if a rod of carbon were electrically heated when submerged in a liquid hydrocarbon under high pressure. Benzine, kerosene, treacle, chloride, and bisulphide of carbon were tested under a pressure of 2200 atmospheres, or about 15 tons per square inch. The results were not successful in producing a hard coating to the rod or in increasing materially its density and hardness except in the case of tetrachloride of carbon, which slightly consolidated and hardened it; on the contrary, the carbon deposited from the liquids always appeared as soft amorphous carbon like soot. These experiments were extended by substituting, instead of the liquids mentioned, silica, alumina, and other substances and increasing the pressure to 30 tons per square inch. When the current density was sufficiently increased the rod was converted to soft graphite. Moissan in 1903 expressed the view that iron in a pasty condition was the matrix of the diamond, and that great pressure was the determining factor, which compelled a minute fraction of the carbon present to appear as diamond; he further referred to the probability that carbon is liquefied when under a pressure sufficient to prevent its volatilization, and that from the liquid state it may pass into the crystalline form on cooling. Crookes, in his lecture delivered before the British Association at Kimberly in 1905, emphasised the same view as to the probability of the crystallisation of carbon directly from the molten state on cooling.

Though my original experiments in 1888 were not favorable to these views, it nevertheless seemed desirable to carry the investigations up to the greatest possible pressures attainable. Experiments were, consequently, resumed in 1907 with a new equipment, which consisted of a 200-ton hydraulic press and a storage battery of 360 kilowatts output. The battery can be coupled for 2, 4, 8, 16, or 48 volts as required, and the mains and the main switch can carry currents up to 80,000 amperes to the hydraulic press, which is placed by itself in a small, strong house partly below ground, with walls of 2 ft. thickness reinforced with steel bars; the door is of steel 3 in. thick, and the roof is of light galvanised iron. The container under the press is further enclosed by 2 in. thick telescoping steel rings, raised into position by steel ropes and counter-weights. These precautions, as experience showed, were necessary, as several violent explosions occurred which cracked the steel rings and blew off the roof. A charge of iron and carbon, when confined and raised to a high temperature, may be very violent if suddenly released by the melting of the pole-pieces; also some endothermic compounds have been formed which swelled the container and allowed the contents to escape.

My experiments confirmed the conclusion at which Threlfall had independently arrived: that under pressures up to 100 tons per square inch and very intense heating by electrical current, graphite is not materially changed. But modifications in the experiments were made and other methods adopted, as will be explained, which in some respects carried the investigation to still higher pressures and temperatures; these, however, lead to the same conclusion.

I propose this evening to deal chiefly with the practical or engineering side of the subject, and to review the limits of pressure and temperature which are artificially attainable, and to make some comparison between them and the pressures and temperatures occuring in Nature.

When the blade of a knife is pressed strongly against another blade so as to make a dent in each, the pressure on the boundary surface of the metal at the notch will have averaged from 300 to 350 tons per square inch according to the hardness of temper of the steel. The pressures of the knife-edges of a weighing machine when fully loaded are also of the same order.

When a needle is broken or a piece of piano-wire is strained to the point of breaking, the maximum tension on the metal will be at the rate of 150 tons per square inch. On the other hand, the pressures that occur in the chambers of large guns do not usually exceed 20 tons per square inch, and the tensile stress on the plates of a ship in heavy weather should not exceed 8 tons per square inch. From these simple instances some idea is gathered of the limitations imposed by materials and dimensions upon apparatus for experimenting at high pressures because of the practical difficulty of hardening and tempering steel in large masses.

When dealing with small amounts of material in each ex-

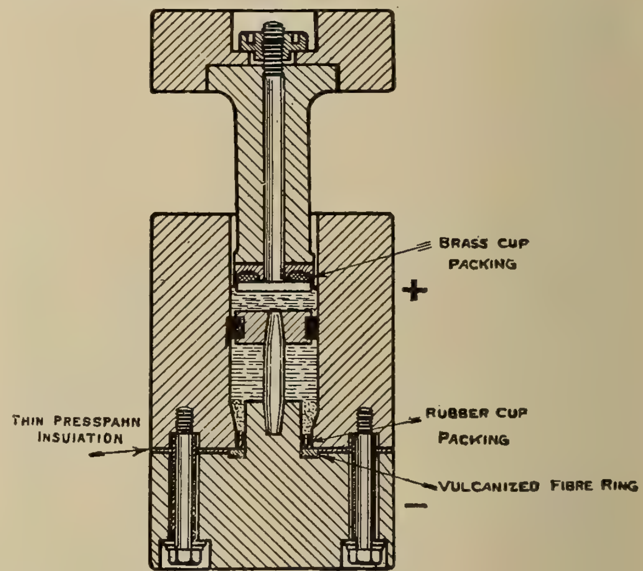


FIG. 1. CONTAINER ADAPTED CHIEFLY FOR COMPRESSING LIQUIDS

periment the dimensions permit of making the container and the ram of tungsten steel, which can be hardened and tempered throughout, and not only superficially, as in the case of ordinary carbon steel. The material is hard and strong, but not brittle, and it retains these qualities up to moderate temperatures, such as 600° C., to a much greater extent than any other steel.

In one form of container or dies the bore is 1½ in. in diameter, and it may be used for a limited number of times for a pressure of 200 tons per square inch. It will, however, eventually crack if this pressure is many times repeated, the crecks usually beginning near the bottom of the die.

For still higher pressures it is better to use a double re-entrant container with two rams ½ in. in diameter. Both the container and the rams are made of hardened and tempered tungsten steel, and are rendered fluid and gastight by mild steel cups on the ends of the rams.

If the charge occupies only a short length of the bore, as shown, the barrel of the container where the charge lies is supported by the shear strength of the metal above and below the zone of pressure in addition to its own strength as a tube. Under these conditions it is as strong as or stronger than the crushing strength of the rams, and pressures of 300 tons per square inch may be repeated several times without cracking.

In a container of this form several grains of fulminate of

mercury have been placed, embedded in graphite, and the pressure increased very gradually until it reached 230 tons per square inch (under this treatment fulminate does not usually detonate). The die was then heated by gas to more than 180° C., the temperature of detonation. After two failures of the experiment, owing to the leakage of the steel cups, the third was successful, and no gas escaped and the container was uninjured. The graphite was somewhat caked, but otherwise unaltered. Graphite mixed with sodium nitrate and fulminate was also exploded under the same condition. Graphite with 15 per cent of potassium chlorate detonated when 200 tons per square inch had been reached.

Many other reactions were tested in a similar manner in larger dies under pressures of from 40 to 200 tons. The action of concentrated sulphuric acid on sugar was accelerated by a pressure of 50 tons, but, on the whole, these experiments in dies failed to produce any interesting results.

Unfortunately, the heating of the die with its charge cannot be carried much above 500°C. without serious weakening

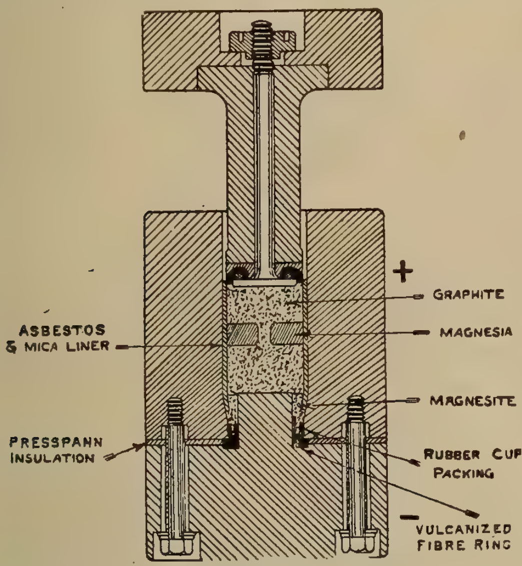


FIG. 2. CONTAINER FOR MELTING CARBON

of the steel and compelling a reduction of pressure. The electrical heating of the charge in such small dies, while keeping the die cool, presents great difficulties in electrical insulation on so small a scale to withstand intense pressure, but I think it might be accomplished in certain instances.

It has been suggested, with the object of reaching higher pressures, that a small die might be bodily immersed in a large container. Doubtless it could be arranged, but it would be very cumbersome to work with, and would only add about 100 tons per square inch to the maximum pressure.

A better plan would be to follow the principle of the usual capped armour-piercing projectile, and to reinforce the rams and ends of the container by tightly fitting copper or bronze rings around the necks of the rams, keeping the parallel part of the noses as short as possible.

When in operation the copper rings will be flattened and squeezed against the necks and shoulders of the rams, and also against the ends of the container, and by this means the parts that ordinarily would have to bear the maximum stress will have part of this stress transferred to other parts not so heavily stressed, and, consequently, the maximum pressure in the container can by this means be raised considerably, perhaps to 450 tons per square inch.

In carrying out experiments on larger samples of material and in applying electrical heating to the charge, the container becomes too large to permit of its being made of hardened steel; therefore, nickel-steel is used, as for the barrels of guns. It is heat-treated by quenching in oil from a high temperature after rough machining. Containers (Figs. 1 and 2) with the thickness of wall equal to the diameter of the bore will stand an internal pressure of 40 tons per square inch repeated almost indefinitely without serious enlargement of the bore, but 100 tons necessitates reboring and fitting of new packing to the ram after each experiment.

Fig. 1 shows the arrangement for electrically heating conductors immersed in fluids under high pressure. The packing of the ram is a cup leather-backed by a cup of brass; the leather first takes the pressure, and the lip of the brass cup is thereby expanded tightly against the bore of the container, and remains fluid-tight even though the leather should be carbonised by the heat. The bottom pole is electrically insulated from the container by vulcanized fiber washers and a rubber cup-ring, which is proteced from the heat by magnesite stemming.

The current is conveyed lrom the container to the top pole-piece of the conductor by pads of copper gauze, which can slide easily against the bore of the container and allow for the expansion of the conductor. Experiments on liquids with this container under 4400 atmospheres gave the same results as my former experiments under 2200 atmospheres.

Fig. 2 shows the container arranged to melt graphite under pressure by resistance heating. Here the charge is graphite, and is divided by the bridge or ring made of pressed calcined magnesia or titanium oxide. The bore of the container is electrically insulated from the graphite by layers of asbestos, millboard, and mica.

The calories evolved in the combination of graphite and oxygen are about 0.5 per cent. less than those evolved in the combination of diamond and oxygen, indicating that graphite at ordinary temperature is, to this extent, a stable state. The bulk-pressure which has operated in some of the experiments would, however, seem to have been amply sufficient to turn the balance in favor of diamond instead of graphite. The uncertainty, on the other hand, as to the compressibilities and specific heats of the allotropic forms of carbon under high pressures and at high temperatures renders speculation of little value as to what may occur at the melting point of carbon. All we know is that, up to the pressures and temperatures reached in our experiments, no indication of a change from graphite to diamond has been produced. In one experiment very intense heating was applied for five seconds, but sufficient in amount to melt the graphite core six times over, the only result being a slight alteration in the structure of the graphite. The barrier in this experiment was calcined magnesia, and the hole in it was superficially converted to magnesium carbide. It appeared, however, desirable further to investigate the possibility of carbon losing its electrical conductivity when approaching its melting point, as alleged by Ludwig and others, and of shunting the current from itself on to the contiguous molten layers of the insulating barrier surrounding it. There had been no indication of such a change having occurred even momentarily; it rather seemed that the graphite core had been partially vaporised and condensed in the cooler parts of the charge. The experiment was repeated with rods of iron and tungsten embedded in the core, so that should the temperature of volatilisation of the metals under a pressure of 15,000 atmospheres exceed that necessary to liquefy carbon under the same pressure, the presence of these metals, might produce a different result. No change, however, occurred.

Note.—The temperatures at which carbon, iron, and tungsten volatilise under a pressure of 15,000 atmospheres are unknown, but they are probably much higher than at atmospheric pressure.

This experiment also tested iron as a solvent of carbon and as a catalyst from diamond to graphite under a pressure of 100 tons, and showed that under this pressure that action was not reversed.

Fig. 3 shows the container arranged for treating powders by resistence heating with or without the addition of liquids or gases. The electric current is conveyed from the container

to the upper end of the conductor by a layer of graphite which rests on the charge under treatment. The bottom end of the conductor rests on or is spigoted into a cast-iron block which rests on the bottom pole; this block is sometimes partially melted, but can be easily renewed.

The container is charged by first stemming magnesite powder by hand around the bottom pole-piece and block; then the charge is placed on the top and pressed to 5 tons per square inch; the top ram is then removed, a hole drilled through the charge, and the conductor inserted. Liquids, if used, or carbon dioxide snow may then be introduced; lastly, a layer of graphite is placed on the top, and the whole pressed to the desired pressure for the experiment.

In one experiment several pounds of carbon dioxide snow were added to the charge, which consisted of magnesia, and was so arranged that evaporation of the heating carbon rod took place in an atmosphere of carbon dioxide and carbon monoxide under a gaseous pressure of 4400 atmospheres, the condensate resulting being soft graphite. Upwards of two

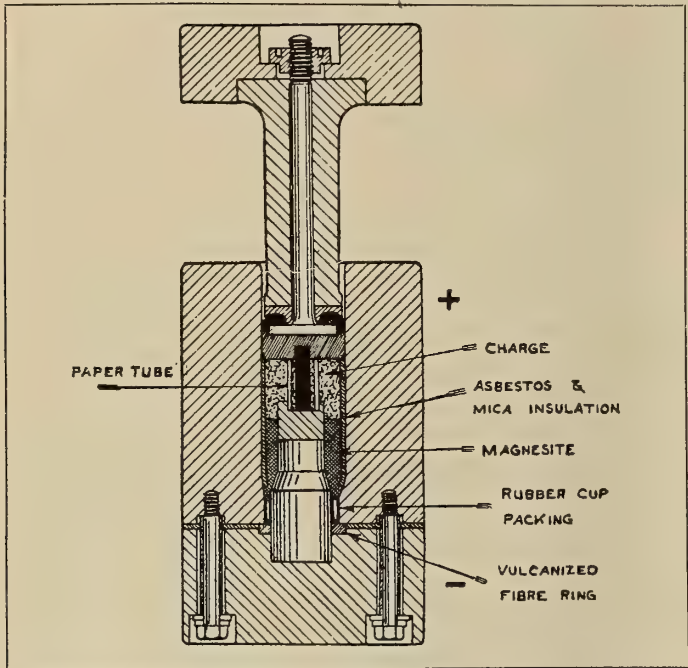


FIG. 3. CONTAINER FOR COMPRESSING POWDERS WITH OR WITHOUT LIQUIDS AND GASES

hundred chemical reactions arranged to deposit carbon were tested under high pressure and central heating. After each experiment samples were taken from various parts of the charge and carefully analysed for diamond, the methods of the analyses generally following those of Moissan and Crookes. On the whole, there was no evidence that diamond had been produced by any of the chemical reactions, some of which were endothermic, such as carborundum and sodium carbonate, which produced a grey solid which detonated when struck with a hammer, and nearly caused a serious accident. In one experiment the charge was olivine and water; when molten under 10 tons per square inch the pressure was suddenly removed, and artificial pumice was formed by the expansion of water-vapor absorbed by the olivine when molten.

Having nearly reached the limits of steady pressure obtainable in steel containers under a press, experiments with impact pressures produced by steel bullets were tried, which produced much higher instantaneous pressures than are obtainable in any die.

A rifle, 0.303-in. bore, was arranged for withstanding a charge of cordite 90 per cent. in excess of the Service charge. The gun (Fig. 4) was fixed with its muzzle 6 in. from a massive block of steel, in which a hole 0.303 in. in diameter had been drilled to a depth somewhat greater than the length of the bullet, and in alignment with the bore of the gun; cylindrical bullets of steel with a copper driving band were chiefly used, shorter than the Service bullet and about one-half the weight. The substance to be compressed was placed either at the bottom of the hole, when a conical-nosed bullet of mild steel was used, or over the mouth of the hole, when a cupped-nosed bullet of tool-steel was employed. About a hundred experiments were made.

The substances tested included graphite, sugar-carbon, bisulphide of carbon, oils, etc., graphite and sodium nitrate, graphite and fulminate of mercury, finely divided iron and fine carborundum, olivine and graphite, etc. After each shot the bullet and surrounding steel were drilled out, and the chips and entrained matter analyzed. Fig. 5 shows the bullet in the hole after firing.

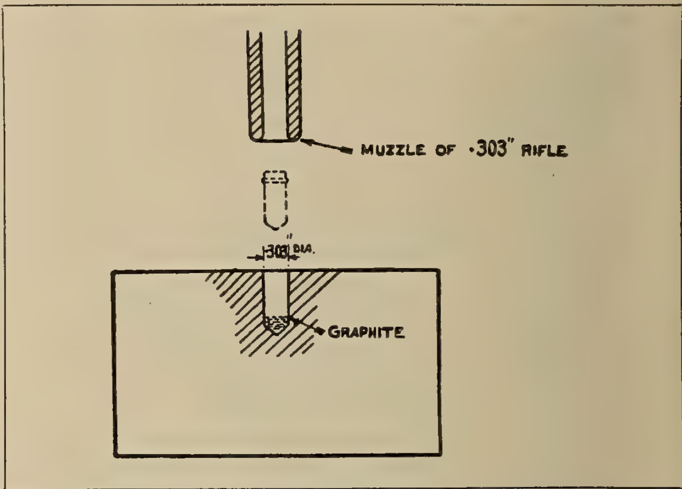


FIG. 4. PRODUCING HIGH PRESSURE BY FIRING A BULLET INTO A HOLE IN A STEEL BLOCK

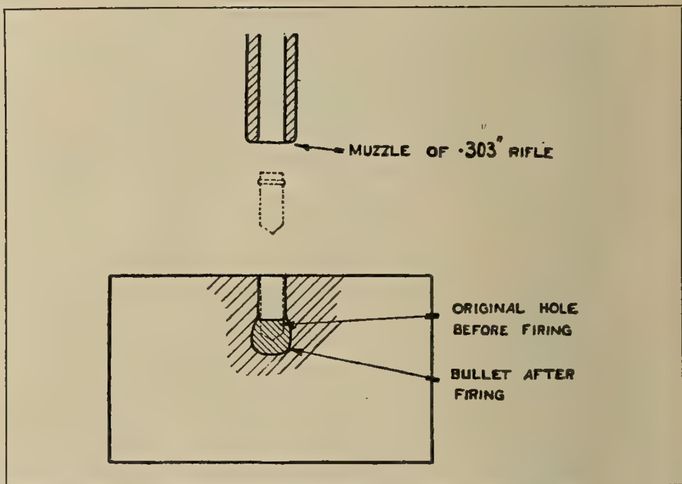


FIG. 5. EFFECT OF FIRING THE BULLET INTO THE HOLE IN THE STEEL BLOCK

Several experiments were also made with a bridge of arc-light carbon placed over the hole and raised to the limit of incandescence by an electric current, and the shot fired through it into the hole at the moment the carbon commenced to vaporise, as observed in a mirror from without. Also, an arc between two carbons was arranged to play just over the hole and the shot fired through it (Fig. 6). The residues were in all cases exceedingly small, and there was no evidence of any incipient transformation of carbon in bulk into diamond that could be detected by analysis.

The pressure on impact of a steel bullet fired into a hole in a steel block which it fits is limited by the coefficient of compressibility of steel; with a velocity of 5000 foot-seconds it is about 2000 tons per square inch. Measurements made from a section through the block and bullet (Fig. 5) showed that the mean retardation on the frontal face after the impact until it had come to rest was about 600 tons per square inch. Several experiments were made by substituting a tung-

sten steel block hardened and tempered, and a hole tapering gently from 0.303 in. at the mouth to 0.125 in. at the bottom. The mild steel bullet was deformed by the tapered hole, which greatly increased the velocity imparted to the nose. Progressively increased charges were used. With the 90 per cent. excess charge the block always split on the first shot, but this probably occurred after impact, and not until the full instantaneous pressure had been exerted, which was probably about 5000 tons per square inch, or about equal to that at the centre of the earth.

It would be interesting to repeat some of these experiments on a larger scale. With a projectile 6 in. or 9 in. in diameter and a velocity of 5000 foot-seconds, the instantaneous pressure would be the same, but its duration (which is proportional to the linear dimensions) would be increased from twenty- to thirty-fold. It has been estimated that the rise in temperature due to adiabatic compression of incandescent carbon when subjected to 2000 tons per square inch is of the the order of about 1000°C., so that actual melting of the carbon would probably have occurred when the shot was fired through the incandescent carbon bridge.

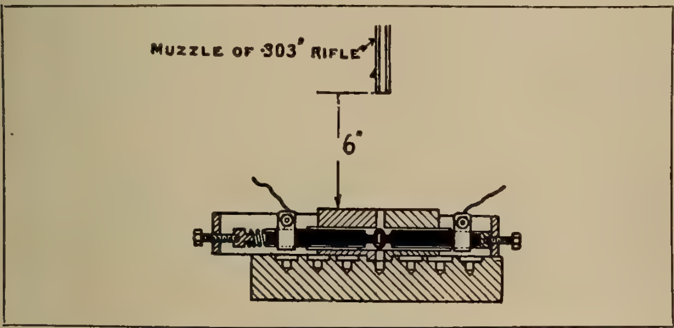


FIG. 6. FIRING INTO THE HOLE THROUGH AN ELECTRIC ARC

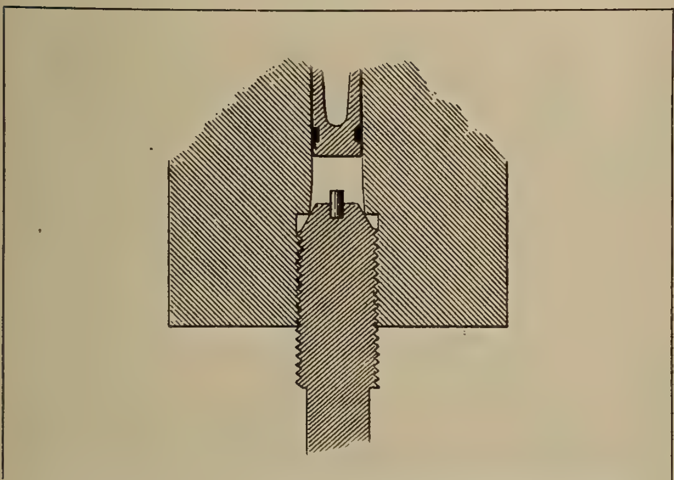


FIG. 7. THE STEEL BLOCK AND PISTON WHICH WAS FITTED TO THE RIFLE BARREL

Another experiment was arranged which would ensure that carbon should be subjected to an extremely high temperature concurrently with a high pressure obtained by the rapid compression of the hottest possible flame, that of acetylene and oxygen, with a slight excess of the former to provide the carbon. The arrangement was as follows (Figs. 7 and 8):— A very light piston made of tool-steel was carefully fitted to the barrel of a gun of 0.9 in. bore; the piston was flat in front, lightened out behind, and fitted with a cupped copper gas-check ring, the cup facing forward; the total travel of the piston was 36 in. To the muzzle of the gun was fitted a prolongation of the barrel formed out of a massive steel block, the joint being gastight; the end of the bore in the block was closed by a screwed-in plug made of tempered tool-steel, also with a gastight collar. A small copper pin projected from the center of the plug to give a record of the limit of travel of the piston. The gun was loaded with 2 drams of black sporting powder, which amount had been calculated from preliminary trials. The barrel in front of the piston was filled with a mixture of acetylene and oxygen. It was estimated that this mixture would explode when the piston had travelled about half-way along the bore. When fired, the piston travelled to within 1/8 in. of the end, as had been estimated, giving a total compression ratio of 288 to 1. As a result, it was found that the surfaces of the end plug, the fore end of the piston, and the circumference of the bore up to ⅜ in. from the end of the plug had been fused to a depth of about 0.01 in., and were glass-hard; the surface of the copper pin had been vaporised, and the copper sprayed over the face of the end plug and piston. The end plug, which had been hardened and tempered to a straw colour, showed signs of compression, and the bore of the block for ⅜ in. from the plug was enlarged by 0.023 in. in diameter, both indicating that a pressure above 100 tons per square inch had been reached. A little brown amorphous carbon was found in the chamber, which was easily destroyed by boiling sulphuric acid and niter. There was no diamond residue from this. Considering the light weight of the piston and the very short duration of the exposure to heat, the effects would indicate that a very abnormal temperature had been reached, many times greater than exists in the chambers of large guns. A calculation made by Mr. Stanley Cook, based upon the ratio of compression and a final pressure of 15,000 atmospheres, indicates that a temperature of between 15,250° and 17,700° C. was reached, the exact temperature depending upon the amount of dissociation or combination existing between the elements at the time.

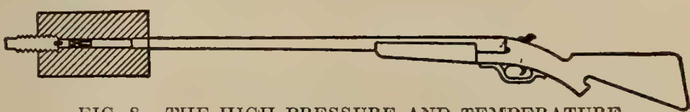


FIG. 8. THE HIGH PRESSURE AND TEMPERATURE EXPERIMENT

Calculation by Stanley S. Cook of the Temperature Reached in the Experiment of Compressing a Flame of Acetylene and Oxygen.

The temperature reached may be estimated from the final pressure, which the observed deformation of the block and plug indicates to have been in the neighborhood of 100 tons per square inch. But it must be remembered that there is a change of molecular volume as a result of combustion. Thus the mixture, which as C_2H_2 and 5(O) has 3½ molecular volumes, would on combustion to $2CO_2$ and H_2O have only 3 molecular volumes. The final temperature deduced from the pressure will therefore depend upon the extent to which chemical combination has taken place.

The original mixture being at atmospheric pressure and at a temperature of 290°C. absolute, a pressure of 100 tons per square inch, after compression to 1/288th of its original volume, would indicate a temperature of 15,250° C. If, however, complete combustion has taken place, this pressure would correspond to a temperature greater in ratio of 3½ to 3, viz., to 17,700°C. The actual temperature must therefore have been something between these two values.

Let us for a moment consider the pressures and temperatures possible in Nature (in this I am indebted to kind assistance from Prof. Jeans). The pressure at the centre of the earth is between 4,000 and 10,000 tons per square inch, according to the variation in density of the concentric layers.

Emden has estimated the probable pressure at the center of the more massive component of the binary star S Hercules to be 360,000,000 tons per square inch.

Again, the densities of the brighter components of certain binary stars are estimated by Opik to be about that of iron, and if we assume that their diameter is the same as that of the sun, that each has an initial velocity in space not greater than 30 miles per second, and that they directly collide, then, owing to their mutual attraction, Jeans calculates that

their velocity will have increased to 450 miles per second, and that the pressures in the center as they strike and flatten would be of the order of 1,000,000,000 tons per square inch. He also estimates that the heat equivalent of the energy would be sufficient to vaporise the whole mass 100,000 times over. This immense pressure would be maintained for many minutes, perhaps for half an hour.

Let us consider what is the greatest pressure that can be produced artificially. If the German gun which bombarded Paris were loaded with a solid steel projectile somewhat shorter and lighter than the one actually used, a muzzle velocity of about 6000 foot-seconds might be reached (many years ago Sir Andrew Noble had reached 5000 foot-seconds); and if it was fired into a tapered hole, as I have described, in a large block of steel, this would give the greatest instantaneous pressure that can be produced artificially so far as we at present know, viz. about 7000 tons per square inch; it is only about 1/150,000th part of that possible by the collision of the largest stars.

As to the temperature and conditions of matter under these intense pressures, extrapolation from known data is valueless. We have no knowledge of the coefficients of compressibility of matter under these conditions or of its specific heat. What may be the effect on the atom? And will elements under such conditions be transformed into others of higher atomic weight?

Some of us may recall that in 1888 a lecturer, after describing in this room the experiment in which oxygen at atmospheric pressure was passed in close contact with a platinum surface heated by the oxyhydrogen burner to nearly its melting point, and then immediately cooled by contact in water, said:

"In this experiment ozone is formed by the action of a high temperature, owing to the dissociation of the oxygen molecules and their partial recombination into the more complex molecules of ozone. We may conceive it not improbable that some of the elementary bodies might be formed somewhat like the ozone in the above experiment, but at very high temperatures, by the collocation of certain dissociated constituents and with the simultaneous absorption of heat."

It seems indeed probable that the centers of the great stars and stars in collision may be the laboratories where the elements as they gradually degenerate are being continually regenerated into others of higher intrinsic energy, and where endothermic processes, such as the recombination of lead and helium into radium, may be taking place, absorbing in this process an energy 2,500,000 times that developed by the explosion of an equal weight of T.N.T.

The transformation of only a minute fraction of the mass of two colliding stars would therefore be amply sufficient to absorb the whole energy of their collision.

Emerson said many years ago, "None but the elements can themselves destroy."

Manufacture of Carbon Black from Natural Gas*

Utilization of Low Pressure Gas in Fields Abandoned by Gas Companies

By Roy O. Neal

THERE seems to be some confusion between the terms carbon black and lamp black, although in American trade lampblack is generally understood to be a soot formed by the smudge process. In this process oil, coal tar, resin or some solid, or liquid carbonaceous substance is burned in an insufficient quantity of air, while on the other hand carbon black is a product resulting from the incomplete combustion of gas and is deposited by actual contact of flame upon a metallic surface.

The various carbons, such as gas retort coke, oil retort coke, graphite, carbon black, lampblack, vine black, wood pulp black, willow charcoal, and blacks made from refuse material such as leather have different characteristics as to flocculence, strength of color, and physical structure. These blacks are made by one of the following methods:

(1) Formation by direct contact of a flame upon a depositing surface.

(2) Production by combustion of an oil, tar, etc., in an inadequate supply of air; the soot is allowed to slowly settle out on the floors and the walls of the collecting chambers.

(3) Carbonization of solids and subsequent reduction to a state of small subdivision.

(4) Production by heating carbonaceous vapors or gases to a decomposition temperature by external heating, with or without air in the forming chamber.

Each black has its specific use that in most cases cannot be met by another black. It is often difficult to apply the usual tests to determine which to use on account of the modification in properties upon combination with other substances. In what follows the black resulting from the incomplete combustion of natural gas is taken up and is designated as carbon black although often in the trade it is referred to as gas black, natural gas black, ebony black, jet black, hydrocarbon black, satin gloss black, and silicate of carbon.

The estimated production of carbon black for the year 1918 was 43,500,000 pounds, of which 30,000,000 pounds was manufactured in West Virginia, and only 1,500,000 pounds was manufactured in Oklahoma. This year will probably show a decrease in production of West Virginia and a material increase for Louisiana, where a large number of plants have recently been built. In the Monroe, Louisiana, gas field, which is probably the largest in the world today, the gas can be obtained for two cents per thousand cubic feet, whereas in West Virginia the carbon-black operators are paying about three cents. The industry is necessarily a migratory one and usually finds its home in an isolated district where there is an abundant supply of gas with insufficient marketing facilities. Judging from plant production, the average yield of carbon black in pounds per thousand cubic feet is probably 0.85 for Louisiana, 1.10 for West Virginia, 1.1 for Oklahoma and 1.4 for Wyoming.

The estimated distribution of carbon black per annum is:

	Lbs.
Rubber industry	20,000,000
Printers' ink	10,000,000
Export	8,000,000
Stove polish	4,000,000
Phonograph records	500,000
Other uses	1,000,000

Under other uses are paint, carbon paper, type ribbon, tarpaulins, carriage cloth, black leather, paper, bookbinders' board, shoe polish, electric composition insulators, celluloid, buttons, etc. At present the export trade is small, pending the establishment of a stable basis of credit with Germany and Austria, but considerable quantities are shipped to England, France, Japan and China. During pre-war times one-third of the annual production was exported.

The first carbon black made in 1872 sold for $2.50 per pound; this price rapidly decreased until it reached the low mark of five cents per pound in 1912. In 1915 support was given the carbon black market when the beneficial results of the use of carbon black in rubber tire-making was discovered. The market price of carbon black has increased and has not since fallen below eight cents, during the past two years it has sold for as much as sixteen cents. The grade

*From Monthly Reports of Investigations of the U. S. Bureau of Mines.

of black above mentioned is that used by the rubber and newspaper ink trade, and constitutes the bulk of the production, although there are some grades, such as the Peerless black that bring as much as thirty-five cents at the present time. The latter is used in limited quantities in making embossing and high grade lithographic ink.

When planning the construction of a carbon-black plant, information on the following points should be obtained: distance from railroad or navigable stream, depth of wells, thickness of gas-bearing strata, gas pressure, gasoline content and knowledge as to whether gas is casing-head or dry, amount of proven territory, history of field, drilling practice, location of field in regard to large centers for domestic and industrial distribution of gas, distance from large trunk pipelines for transportation of gas, open flow capacity of gas wells on prospective leases, and a test on the richness of gas for the approximate quantity of carbon black that one expects to procure per thousand cubic feet.

The carbon black value is determined either by chemical analysis of the gas or by a test apparatus in which a known quantity of gas is burned and the carbon black that is deposited upon a plate is collected and weighed. By chemical analysis the yield of carbon black is computed from the percentage of ethane, heating value, and the carbon content. Louisiana gas contains 3.44 per cent ethane, has a heating value of 962, a carbon content of 33.8 lb. per thousand and only 0.8 of a pound is obtained per thousand cubic feet; whereas Wyoming gas which contains 43.1 per cent ethane, has a heating value of 1176, and a carbon content of 44.3 lb. per thousand, the yield is 1.4 pounds. There are four commercial processes of making carbon black classified according to the quantity of carbon black produced. The order is as follows: channel, small disk, large plate and roller processes.

CHANNEL PROCESS.

Briefly the channel process is as follows: The gas from the wells is reduced in pressure by suitable regulators, and then goes through gasometers that regulate the flow by a butterfly valve. The gas then passes to the burners in the condensing buildings, special precautions being taken in the pipe-line design to obtain equal distribution of gas in all the buildings. The condensing buildings are sheet-iron buildings about 100 feet long and from 10 to 8 feet in width, arranged in rows along both sides of an alley. Through the center of the alley, and at right angles to the condenser units, is the main driving shaft, which operates the machinery within the units.

On the interior of the buildings are tables of channels, beams having eight 8-inch channels that travel on trucks supported by a trestle 6 feet high and 66 inches wide. The channels have a reciprocating motion of about 55 inches. The gas is burned through ordinary lava tips with an even, luminous, and smoky flame, the draft being regulated by a slide door or slits at the base of the buildings or by the chimneys. There are about 1600 tips per building. The carbon black is deposited upon the underside of the channels. Underneath the channels and spaced every four feet are sheet-iron hoppers to catch the carbon removed by scrapers set in the hoppers. Connected to the hoppers is a spiral conveyor that carries the black to the bolting room. The bolters are galvanized sheet-iron drums having a layer of 45 to 60-mesh iron screen held by heavy wire as reinforcement over which fiber brushes rotate; the purpose of the device is to remove grit, scale and like material. From the bolters, the product is elevated by an endless chain to a storage bin, whence it is packed in 12½-pound sacks.

The plants are usually built in 60-barrel units (50 pounds per barrel) and have 18 buildings. The channels and other moving mechanism weigh about 200 tons. This is actuated by a 20 to 25-h.p. internal combustion gas or expansion engine. The operating cost is about 2 cents per pound (exclusive of cost of gas) and the construction cost at present is about $2,500 per barrel per day.

ROTATING DISK.

The disks are made of cast iron, 36 to 40 in. diameter, having a 6-in. face and, together with the gear and pinion, resemble flat umbrellas. The hopper and scraper radiate from the shaft and, like the burners, are stationary. The burners are in the form of rings with lava tips inserted about the upper part of the ring. The disks are set in rows of 21 each, with four rows to the condensing building, and a separate driving shaft for each row of disks. The pinions are of special design having teeth about 4 inches wide that mesh with 2-inch teeth on the gear. This arrangement is to take care of expansion and contraction. Other details of the plant are the same as in the channel system.

PLATE PROCESS.

The plates upon which the carbon black is deposited are 24 feet in diameter, and made up of 48 segments, which are supported by a central mast and cables. The plates are stationary while the burners and scraper rotate, making one revolution every eight minutes. There are 1265 tips to each plate. The plates are surrounded by a circular building 26 feet in diameter, made of corrugated sheet iron. The conveyor system, bolting, and packing process are the same as in the preceding systems. One company has as many as 113 rings and a daily production of 10,000 pounds.

ROLLER METHOD.

In the roller process the gas is burned through lava tips, having a round perforation instead of fish tail. The rollers are 8 inches in diameter and three feet in length, making one revolution in thirty minutes. The scrapers are set on top of rollers and scrape continuously. From 6 to 9 rollers are inclosed in one hood. In one plant visited there were 1150 rollers and 40,000 tips, with a production of only 300 pounds per day. The yield per thousand cubic feet is very small but the product commands a high price, about 35 cents at present. It is used in making embossing and high grade lithographic inks.

THERMAL DECOMPOSITION.

Thermal decomposition, or the subjection of oil vapors or gas to cracking temperatures with or without the presence of air, is not a commercial success at present inasmuch as the resulting carbon is heavy, contains tarry matter and is off color. A company in western Oklahoma erected a cracking chamber for making black from natural gas and found that the product was salable. A jobber said that it was not good for any purpose except perhaps to blacken the face of a minstrel. The process, however, furnishes a promising field for future research. Possibly by using a properly designed cracking chamber, sudden cooling, using some catalyser, employing pressure or the admission of a suitable quantity of air, the process will become a commercial success and capable of producing a black having the same properties possessed by the ordinary carbon black on the market today.

ECONOMICS OF CARBON BLACK INDUSTRY.

It is generally conceded that the most useful purpose that natural gas can be applied to is for domestic consumption, but whether gas is of greater economic value for the manufacture of carbon black than for other industrial uses is a question that must be decided on the basis of conditions existing in each locality in which a large supply of natural gas is available.

The utilization of low-pressure gas, discharge gas from natural gas gasoline plants, gas in isolated districts, and fields which have been abandoned by other gas companies on account of low pressure, for the manufacture of carbon black, is in reality often a conservation measure and is preferable to the common practice of letting the gas go to waste.

The utilization of natural gas for domestic consumption is possibly the most beneficial use that can be made of gas, and it is not recommended that gas be used for the manufacture of carbon black where there is an available market for the gas for domestic purposes.

High Temperature Electric Heat-Treating Furnace

Development Due to the Emergency of the War

By Geo. H. Holden, Assist. Inspector of Ordnance, U. S. N.

BEFORE the declaration of war against Germany, the naval arm of America's military establishment had made an intensive survey of the varied industrial facilities. This, to a large extent, had been prepared through the assistance rendered by combined engineering societies to effect a complete industrial inventory, which, at the outbreak of the war, was practically compiled, so that sources of all material were available. Thus the naval program of expansion—preparation—perfection—permitted the Navy Department to place large contracts with America's chosen industries, whose later accomplishments, excessive production and excellence of quality would be recorded of the stimulus and foresight of the preparation already outlined.

To produce guns to fit out this large naval expansion was of such magnitude that it would confound any citizen not familiar with the activities incident thereto. The arming of all transports, supply boat, sub-chasers and tugs was imminent.

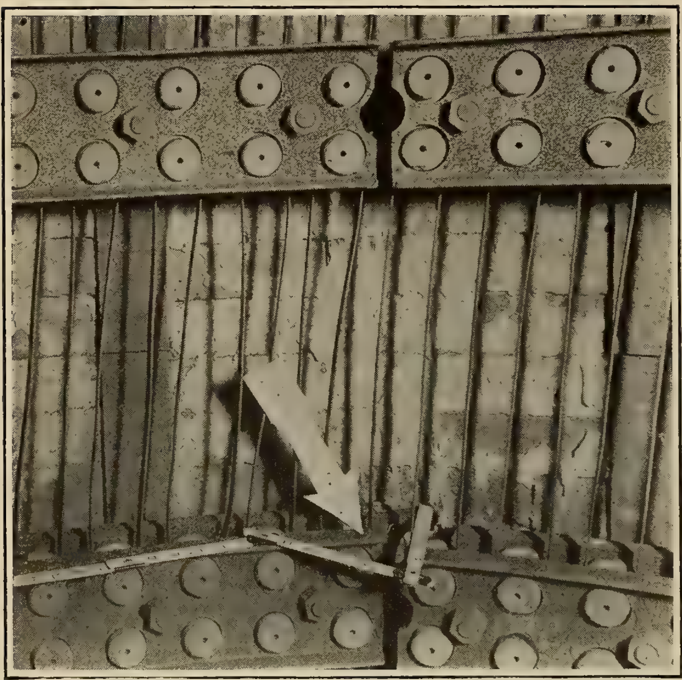


FIG. 1. EFFECT OF VARIATIONS IN EXPANSION OF THE PORCELAIN REFRACTORY INSULATORS

Also to insure that sea food would be available for our large growing population it was even necessary to arm the offshore fishing boats. As the reader will recall a number of atrocities were committed within the three-mile limit of our eastern shores by German marauders.

The supply of gun forgings was confined to a half dozen manufacturers throughout the United States. The tonnage which the Navy demanded was only obtainable through immediate expansion and even though this expansion could not be readily accomplished, because the foregoing companies were worked to capacity, they did not have the capital sufficient to expand to meet the emergency demands of the Navy and further did not care to assume the risk of the war's terminating, possibly, before emergency extensions were accomplished. The War Industries Board, which had cognizance of the manufacturing facilities, directed, therefore, that expansions be made and subsequently cost-plus contracts were entered into whereby the cost of expansion of various plants was paid for by the Government, the manufacturer assuming the responsibility of operating and producing material required.

The writer will endeavor to present the actual production, on a major basis, in connection with the heat treatment by high temperature electric furnaces, on one of the large contracts.

Prior to the actual construction of these furnaces considerable discussion was entered into as to the practicability of installing this type of furnace, owing to the fact that such data available was anything but encouraging and generally considered still in the experimental stage, as during 1915 and 1916 one of the large steel companies had conducted extensive experiments with several high temperature furnaces both of the experimental type and the commercial, and had collaborated with prominent electrical authorities to the end that considerable success and information was obtained.

The following points are briefly presented for analysis, which will express characteristics both favorable and unfavorable, based largely on the fact that maximum temperatures

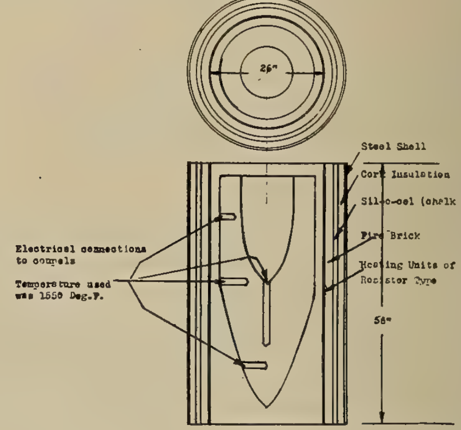


FIG. 2. EXPERIMENTAL FURNACE OF RESISTOR TYPE

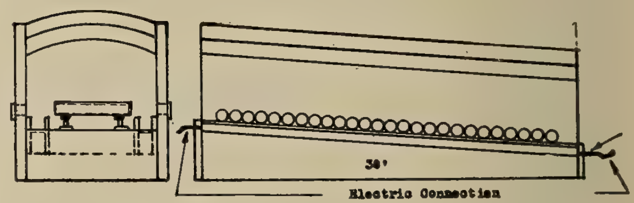


FIG. 3. LATER TYPE OF FURNACE EMPLOYING A BED OF GRAPHITE FOR THE HEATING ELEMENT

of at least 1,600 degrees are necessary in treatment of steel forgings. This particularly in such cases as do not respond to the required static covered in the specifications.

In connection with a few electric resistor type furnaces, the low temperature type has proven a success and it can be said that the experimental stage is over and was used extensively during the war for shrinkage and general manufacturing purposes where temperatures ranged 1,000 degrees F. or less.

Where maximum temperatures exceed 1,000 degrees F. the electric furnaces have the following invaluable characteristics.

The insulation, which to date 1917 has been adapted, has been absolutely erroneous and to some extent has been partially overcome, therefore, this type of furnace is still in the experimental stage and certain phases of the same when overcome will prove that the prospects are very hopeful.

It is most important that construction of furnaces be such that no metallic members be directly exposed to the high tem-

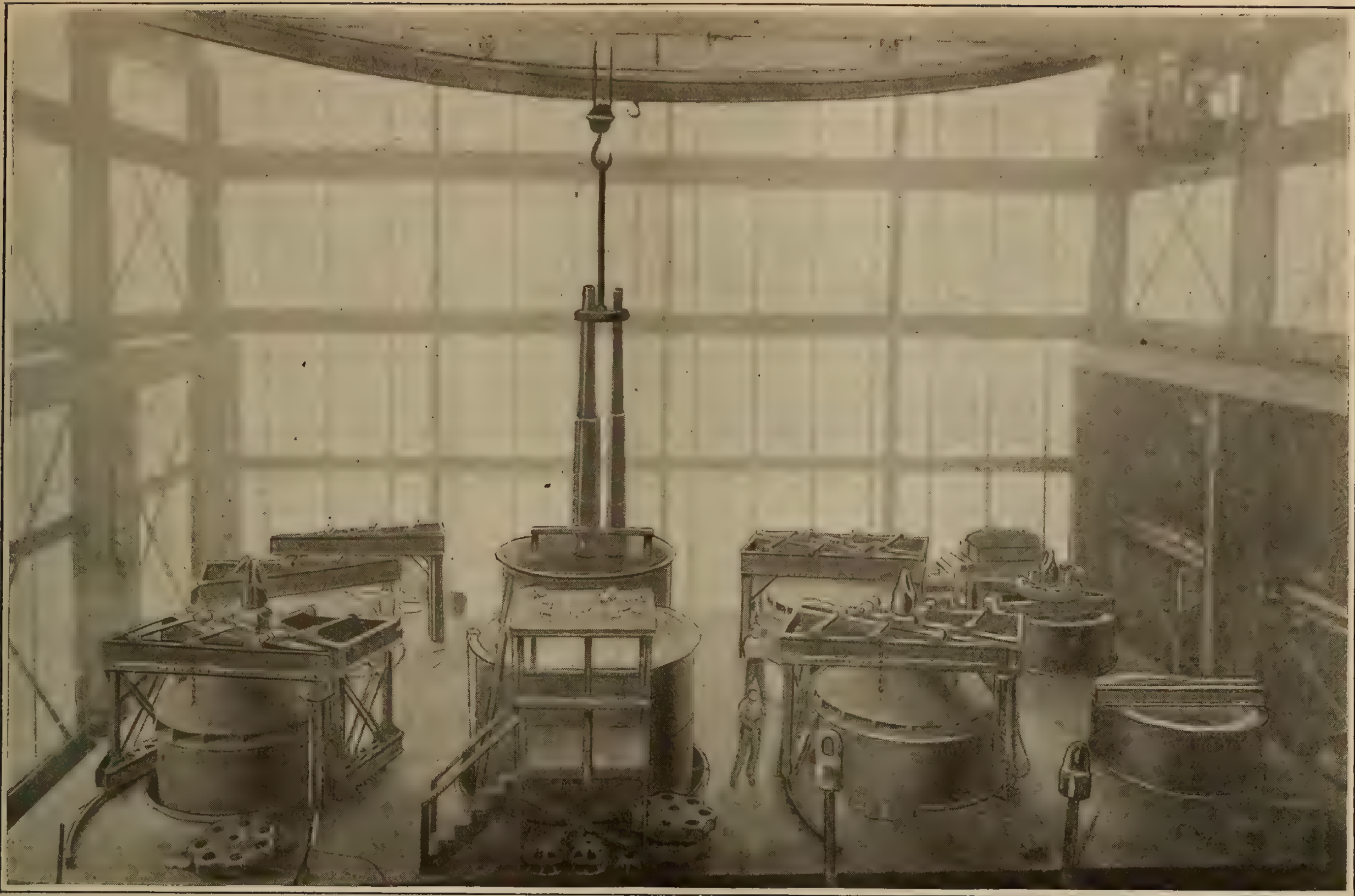


FIG. 4. ELECTRIC FURNACE EQUIPMENT APPROVED BY THE NAVY DEPARTMENT. FOUR HIGH TEMPERATURE RESISTOR TYPE FURNACES, TWO QUENCHING TANKS WITH CAPACITY OF 11,800 CUBIC FEET OF WATER AND TWO COOLING STACKS

peratures due to coefficient of extension or expansion and contraction of same, except when adaptability will prove practicable and where furnace design will compensate for same, as past experience has taught and demonstrated that simplicity and extreme strength are most essential when dealing with high temperatures.

As an illustration of this fact the Bureau of Standards in Bulletin No. 352 entitled Thermal Expansion of Insulating Materials, and No. 357, Coefficient Radiation, presents excellent data. In most cases the expansions are too irregular to justify the use of the general quadratic equations, but a thorough knowledge of the thermal behavior of the various materials which enter into the construction of this type of commercial furnace, will assure considerable success to the practical application of this theory, and the initial cost of installation.

The procelain refractory insulators used for suspending ribbons have a wide range of the coefficients, namely, from 1.6 to 19.6 millionths per unit length per degree centigrade. While this is considered insignificant from a practical point of view, its relation is obvious, however, when used in connection with the columns and channels of a metallic composition having a coefficient of extension expressed in inches, as will be noted in Fig. 1.

The point-contact couplings at best are unsatisfactory as the pressure to be applied is uncertain and so important. At best the utmost skill and patience is required to obtain temperatures and results are unreliable, as check temperatures are desirous at times in order that forgings may be successfully treated.

It is most indispensable that a coupling contact be made at point of diffusion in order that temperature of furnace may be controlled, as in treatment of forgings in multiples or hollow bored forgings. The furnace temperature proceeds at a more rapid rate in rising than the forging and to obtain uniformly heated forgings they must be allowed to saturate to the furnace temperature.

The various steel companies manufacturing gun forgings have attained a point of highest efficiency in the production of the same with the vertical oil-fired furnaces in which the human element is a large factor or characteristic concerned, particularly in keeping the temperatures throughout the length of forgings at a uniform temperature, or where a tapered temperature is desired, owing to the varying cross-sections of forgings.

If this uniform temperature is not maintained when forgings are quenched and subsequently drawn and tested non-uniform results in physical tests will be obtained.

One of the early experimental types of this resistor type of electric furnaces was successfully used in the heat treatment of 14-in. A. P. shells, but not until after the foregoing invaluable characteristics had been overcome, and it is not surprising that the experiments having this success had run over a period of one year, conducted by two leading electrical engineers.

This furnace, as shown in Fig. 2, was 26 in. inside diameter and 60 in. high. It was circular and a resistor type unit from which the treating plan under discussion was developed. At first, no control at point of diffusion was made and when the furnaces had attained the desired temperature current was cut out and before shell forgings was allowed to saturate uniformly throughout, the temperature at points where couplings had been inserted (in drilled holes) showed excessive variation, which should not vary more than five degrees to insure proper treatment. Subsequently couplings at point of diffusion were attached.

Another high temperature furnace was developed and after nine months of constant experimenting some success was at-

tained in the treating of 11½ in. French shells on a commercial basis. As may be seen in Fig. 3, this furnace had a refractory lined conduit on each side and the furnace was of the arch type gravity feed. About two bushels of graphite was consumed in 24 hours as the heating element. The graphite was laid uniformly along these conduits or troughs through openings at the ends and sides of furnace, thereby completing the electric circuit. The graphite was renewed constantly by laying same with a long handled shovel at points where graphite was about burned out. The uniformity of heat diffusion was controlled by this unique method of keeping the graphite at a uniform depth. This type of furnace gave constant trouble and was subsequently refitted with oil.

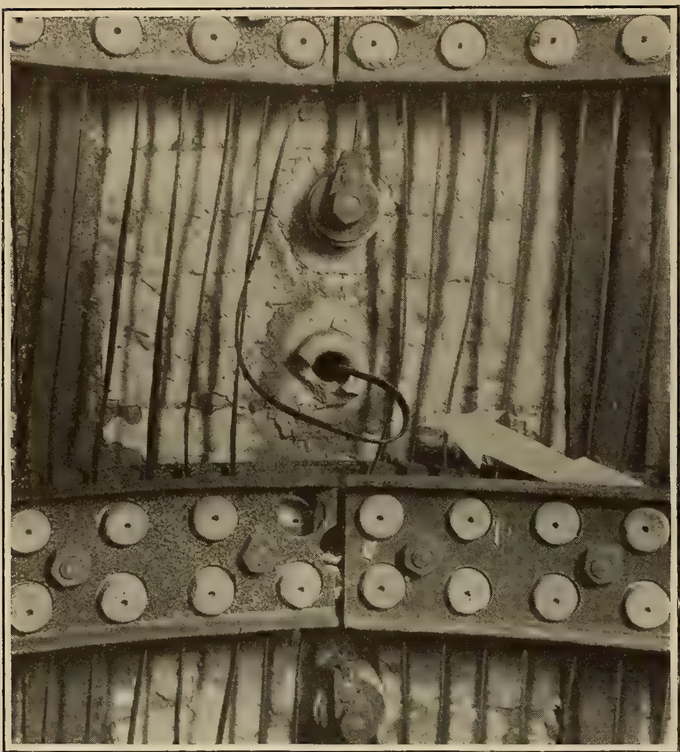


FIG. 5. THE NICHROME RIBBONS CONNECTED TO THE TERMINAL RODS

It was, therefore, recommended by officials familiar with the foregoing difficulties that two of the battery of electric furnaces be fitted with oil type connections to insure against delay in case any unforeseen difficulties should arise in the successful operation of these furnaces.

The contract required the total delivery of 5,000,000 of 3 in. and 4 in. gun forgings, delivery to begin six months after date of contract, to wit: 90 sets of 4 in. and 50 sets of 3 in. guns, per calendar month—or approximately 600,000.

To accomplish the heat treating of this large volume of material the company that received the contract were desirous of treating same by the electric process, which was a new departure unheard of on a commercial basis. However, with the Navy Department's approval, a proposition was received from one of America's leading electrical manufacturers, which submitted a proposal to install four high temperature heat treating furnaces and received a tentative contract during July, 1917, to proceed with the construction of the same.

Specifications

Furnaces—27½ ft. high, 6 ft. inside diameter.
High Temperature Hardening Furnace, 400 Kw. 440 volts.
Operating temperature 1,500 degrees F. Max.
Charge—16,000 pounds steel.
Thermal capacity, 1,500 degrees F. (2,000 Kw. H. Approx.)
Radiation—50 Kw. H. (Approx.)
Furnace constructed per G. E. design, 9 in. heat lagging.

Guarantees.

Operating at 440 volts, (A) Furnace at 600 degrees F., charged with 16,000 pounds steel at 60 degrees F., economy will be not less than 6 pounds per Kw. H.; Cycle of heating—6 hours. (B) Furnace at 1,500 degrees F., charged with 16,000 pounds steel at 60 degrees F., economy will not be less than 8 pounds per Kw. H. Cycle of heating—3½ hours. Allowing 1 hour for forging to soak at 1,500 degrees F.

The electric furnace, as approved by the Department, Fig. 4, was to consist of four high temperature resistor type furnaces, two quenching tanks of 11,800 cubic feet of water capacity and two cooling stacks. Furnaces were made up of a steel shell 10 feet in diameter in which a 12 in. floor of fire brick, asbestos cushioned was laid. In a vertical position a metal column frame of calorite metal was erected. After the calorite frame was set, centered and shored, a refractory lining was inserted between it and the steel shell, and starting from the frame studs, consisted of one row of high grade silica brick backed by two rows of "Silocel" and a packing of about two inches of wool asbestos. The furnace face of this lining was then grouted and made air-tight at all joints. Special refractory tube insulators afforded entry for terminal rods. between channels, spools of highly refractory (silica) material was inserted and on these a nichrome ribbon was wound.

This winding is well illustrated in Fig. 5. Resistors or terminal couples are attached and after inspection of ribbons for contacts, the covers of the furnaces are hung. Flanges on the bottom of the cover castings sink into a sand layer on the top of the furnace lining and serve as an air seal. The covers are built up of two sections—half domes—lifted by air valves and supported by a frame superstructure which rolls out from furnace on standard rails and thus give clearance of the full

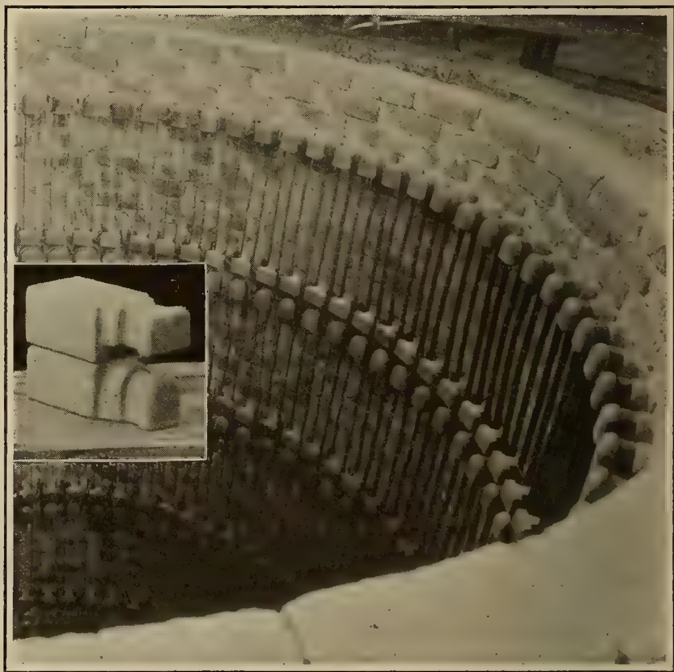


FIG. 6. IMPROVED DESIGN OF WALL INSULATOR

diameter of the shell for the charging and withdrawing of pieces treated. The design and operation of these covers are illustrated in Fig. 4.

The temperature range is effective from 800 degrees F. to about 1,800 degrees F. and while a maximum high range of 1,500 degrees F. is used, 300 degrees higher has been attained without inconvenience or danger to insulators or ribbons. The only visible effect was the distortion of the metal frame-work of calorites or aluminum steel. On the experimental bench, ribbons have stood up to 2,500 degrees F. without bad results.

The furnace is divided into four zones each under separate

FIG. 7. THE CONTROL ROOM. NOTE THE OPERATOR SETTING A SWITCH DISK FOR THE MAXIMUM TEMPERATURE DESIRED IN A ZONE OF THE FURNACE

and independent thermal control, which gives greater elasticity of temperature range and enables the metallurgist to compensate by graduated resistance for the idiosyncrasies of transformation in the quench, which affects different sections of metal with greater or less degree of hardness or high static values. Each zone has an independent Leeds-Northrup self-recording pyrometer. The pyrometer is equipped with a three wire motor driven commutator controlling a galvanometer which acts directly upon a switch disc. The setting of this disc governs the maximum temperature desired and the maintenance of that temperature when it is reached. Fig. 7 shows an operator in the act of setting a disc. Hardening and drawing furnaces are operated alike with the exception that while a uniform temperature is maintained on hardening, the graduated or step temperature is applied on draw heats with excellent results in the uniformity of physical characteristics obtained in breech and muzzle ends of parts treated.

The writer will endeavor now to present the actual troubles, developments and rectifications which were necessary to place the foregoing high temperature furnaces on an efficient working basis.

Shortly after assumption of work on these furnaces, it was found that resistor couples, which were of mechanical design, were deteriorating very rapidly and in some cases caused ribbons to become loose, and resulted in arcs which burnt off the ribbons. This caused loss of the zone and necessitated cooling down of the whole furnace to effect repairs—the time loss and overhead costs accumulating through these repairs made the condition serious.

It was found that certain segments and columns were scaling so heavily that large pieces falling on channels between resistance series caused numerous arcs which would also burn nichrome ribbons in two, causing great time losses in operation on account of repairs and replacements of ribbons. At this time unsuccessful attempts had been made to weld burnt ribbons.

The necessity of reducing this time loss resulted in experiments on the welding of nichrome ribbons carried on by manufacturers of these furnaces. Success attended the experiments and a modification was made in the elimination of the mechanical couple, by welding the ribbon directly on the terminal rod. Likewise this welding of nichrome eliminated the mechanical ribbon splice (see Fig. 5). Discovery of air inlets at terminal entrances brought about a correction of heavy scaling problem. A careful seal of all openings, electrical and optical, proved a remedy.

A new trouble developed about 30 days after starting of furnaces, namely the distortion and deterioration of the metallic frames. This had been anticipated and the subsequent elimination of the metallic frame and substitution of refractory insulators, directly into wall, as early as October, 1917, resulted. Owing to the novelty of furnace design and inex-

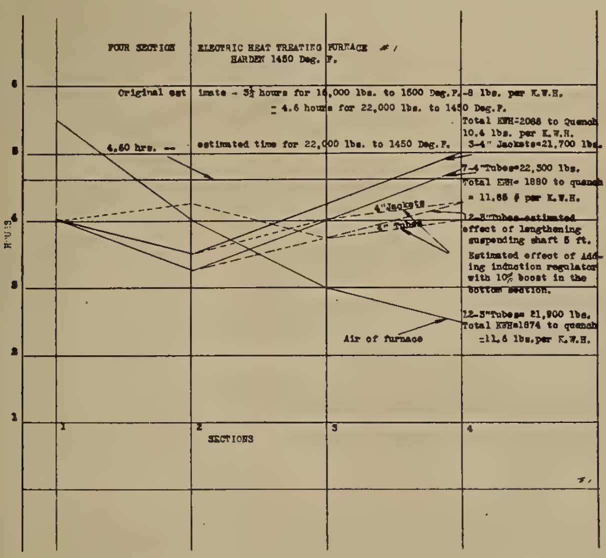


FIG. 8. TIME REQUIRED TO REACH TEMPERATURE FOR 3-IN. TUBES, 4-IN. JACKETS AND 4-IN. TUBES

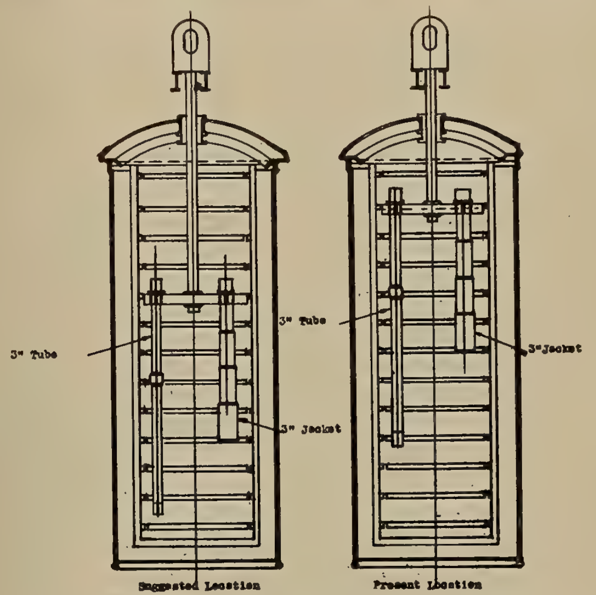


FIG. 9. PROPOSED AND PRESENT LOCATION OF 3-IN. JACKETS AND 3-IN. TUBES IN THE FURNACES

perience of the general heat treating personnel on electric furnace resistance on so large a scale, practical application of this suggestion did not develop at this time. However, distortion developed into such serious proportions that the plug or wall insulator was again given attention and submitted to the Bureau of Ordnance which directed that the furnace be immediately equipped with this insulator, and now it is possible to reduce the initial construction costs of electric furnaces for treating forgings 60 to 70 per cent (see Fig. 6).

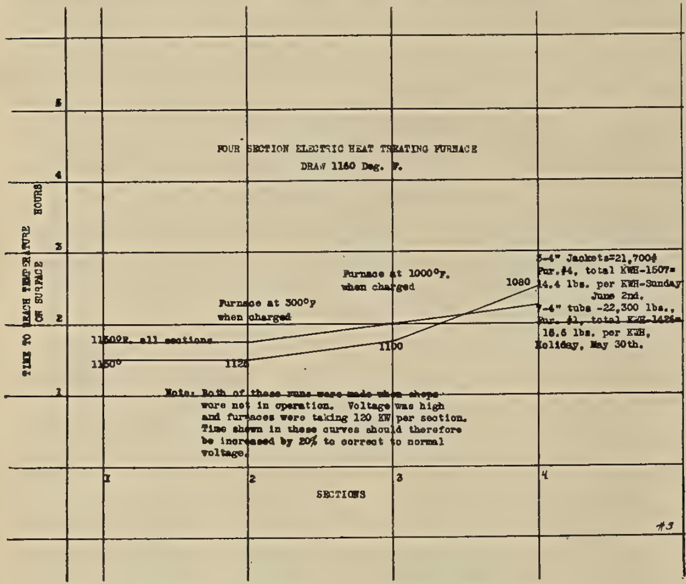


FIG. 10. CURVES OF DRAW IN FURNACES NOS. 1 AND 4. NOTE THAT CURVES CROSS DENOTING DEFECT IN HEAT INSULATION OF FURNACE NO. 1

The innovation of electric furnace heat treating has proved, beyond contention that this method has done more than to compare favorably with the older oil and gas fuel methods. The cost of power consumption as compared with that of fuel oil used in this plant for the heating medium—due to time factors and control of results possible with the electric furnace, and figured pound for pound raised to same temperature and held there—has been approximately 20 per cent lower.

The series of tests referred to in the following remarks were conducted on the furnaces and were made to investigate and check the furnaces while in actual full load operations, one against the other, to check efficiency of same and to see that specifications and guarantee of manufacturer had been met and further to effect proper certification of invoices covering final payment of same.

Fig. 8 shows the time required to reach temperature for 3 in. tubes, 4 in. jackets and 4 in. tubes. It should be noted that the actual charges heated average about 22,000 pounds the weight in the sections varying widely, whereas the original estimates were based on charges of 16,000 pounds, approximately uniformly distributed in the sections.

The curves show that for 4 in. tubes, sections 1 and 3 reach temperatures on the surface in 4 hours, section 2 in 3¼ hours, section 4 in 4¾ hours, making an average of 4 hours. This is almost exactly the estimated time for this weight of charge, which is 4.6 hours for the charge to reach temperature throughout.

Similarly for 4 in. jackets the average time would be 4.2 hours. The extreme time of 5 hours in section 4 being required on account of the concentration of weight in the breech of jacket, and also owing to the fact that the charge consists of only three pieces, presenting comparatively little surface through which heat can be absorbed. This is further emphasized by the curve for 4 in. tubes, which, although being a heavier charge, are heated more quickly with less power, and with a very marked increase in pounds per Kw.H. This is due to the greater surface presented by seven pieces.

Fig. 8 also shows the time required for a charge of 12-3 in. tubes. These tubes are practically the same size for their entire length, but do not reach to section 4. They are supported by a heavy fixture in section No. 1. These conditions are emphasized by the curve, which gives 5½ hours, 4 hours, and 2½ hours for sections 1, 2, 3 and 4 respectively. This, and the curve for 3 in. jackets on next sketch represent extreme conditions of unequal loading. These conditions can be largely overcome by lowering the charges in the furnace, in order to put more work in the lower sections. This may be accomplished by lengthening the suspending shafts five feet and the dotted curves on Fig. 8 show the estimated effect of such lowering. Fig. 9 shows the present location of charges in the furnace and the proposed location of 3 in. jackets and 3 in. tubes, 5 feet lower in the furnaces.

Fig. 10 shows curves of draw in furnaces No. 1 and No. 4. Note that these curves cross. This same phenomenon is shown on Figs. 11 and 12 and is accounted for by a serious defect in the heat insulation in furnace No. 1.

Fig. 12 shows the minimum input to the various furnaces by section, which if added will give the radiation losses of each.

A very marked improvement in the operating cycle was noted from this change of lowering charge in furnace both in time and Kw. H. consumption.

The furnaces were guaranteed to operate an economy of not less than eight pounds per Kw. H. The tests give 10.4 to 11.85 pounds per Kw. H.; depending on the distribution of charge in the sections, and the proportion of weight to surface in the pieces charged. The above is for 3 in. tubes, 4 in. tubes and 4 in. jackets, the 3 in. jackets representing such an extreme condition of unequal loading that no comparison is possible with the original estimate.

In regard to the time of heating, it may be said that the conditions have been adequately met, as the estimate of time covered one condition only, namely; uniform load in all sections, and the furnaces did unquestionably meet this condition.

The various test runs have been plotted against one another to make sure that the furnaces are duplicated. Cut No. 13 shows Kw. H. consumed in each section for three hard-

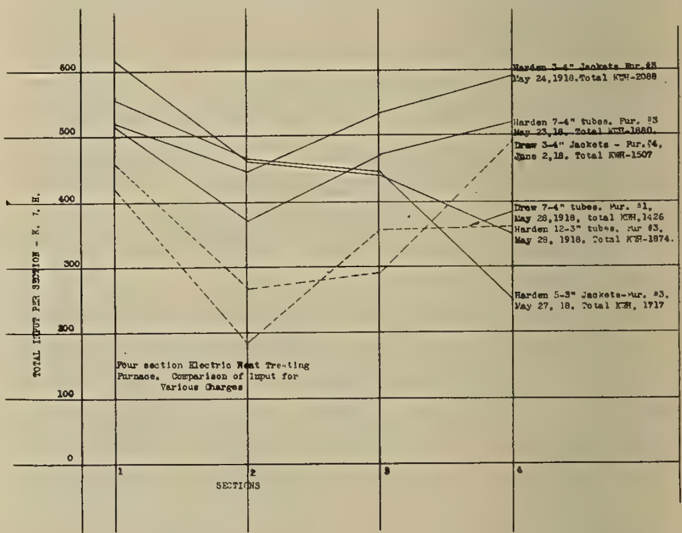


FIG. 11. COMPARISON OF INPUT FOR VARIOUS CHARGES

ening heats of 4 in. tubes, all these taken in different furnaces. Note the curves for furnaces No. 2 and No. 3 are exactly parallel, but furnace No. 2 had not run quite so long as furnace No. 3. If the length of run had been equal the curves would have been exactly superimposed.

The run of Furnace No. 1, however, shows a greater Kw. H. consumption and the curve is not parallel to the other. This leads to the conclusion that there is a crack or other defect in heat insulation of furnace No. 1. This same peculiarity is shown on cuts 16 and 17, and also in the watt meter reading and temperature of casing in the test data, due to distortion of columns and channels embedded into heat insulation.

ELECTRIC SPARKING IN MINES FROM LIGHTNING.

By GEORGE S. RICE and L. C. ILSLEY.

A REMARKABLE explosion of fire-damp caused by a discharge of lightning at the new shaft at the Sitalpur coal mine, has been reported by the Chief Inspector of Mines of India, who gave the following details:

"The explosion occurred during a thunderstorm, and the evidence showed that a flash of lightning had, to all appearances, passed down the shaft causing disruptive discharges at certain points between the guides and the winding rope, rending the latter at two places situated respectively 228 feet and 278 feet from the surface. The distance between the winding rope and the side of the shaft was 5 feet 4 inches, indicating a spark gap of this width, and an intensity of discharge which could not fail to ignite the explosive mixture of gas and air known to be present in the shaft."

The *Compressed Air Magazine*, January, 1920 issue, which contained the above extract also goes on to state:

"In 1915, M. Ferey described in a paper read before the Societe de l'Industrie Minerale phenomena of a similar character to the above. In a pit liable to sudden outbursts of gas, for the sake of safety, shot-firing was carried out from the surface. During a storm, in the year 1905, shots went off in two places after the detonators had been connected to the conductors, we read in the *Colliery Guardian*, London. These shots were situated respectively 1,400 and 1,410 meters from the firing station. Realizing the possible danger from this cause, the precaution was taken to cut the conductors at the bottom of the shaft and to connect them just before firing. Even under these conditions a shot went off spontaneously, owing, it is believed, to lightning."

The Bureau of Mines, when it was investigating shot-firing from the surface some years ago, found a number of cases where lightning had entered underground. In one case in a shallow mine in Pennsylvania lightning entered following the roots of a tree and caused the death of a man in the main entry. In another case, in the Pratt City Mine which came

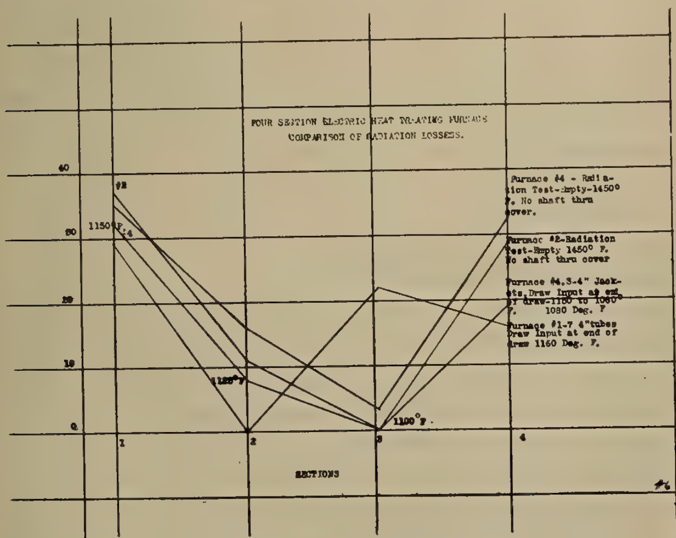


FIG. 12. MINIMUM INPUT TO VARIOUS FURNACES BY SECTION

under the observation of the Chief Mining Engineer, lightning entering on shot-firing wires caused premature ignition and this led to the recommendation of making a gap of about 5 feet in the shot-firing line which was not to be closed by the flexible cable until the men had all been withdrawn from the mine.

Another case reported was that of a mine temporarily abandoned, belonging to the United States Coal and Coke Company at Gary, West Virginia, where an explosion blew up following a flash of lightning which evidently entered the shaft and ignited the fire-damp. The question of providing an arrangement to prevent lightning entering into mines is a difficult one, in mines where electric shot firing on an extension scale is used. The ordinary types of lightning arresters are satisfactory protection against static electric currents produced by lightning discharges, but if a "lightning bolt" actually hits the circuit, there is such an enormous amount of energy to be dissipated that the ordinary devices do not suffice.

Following out the same reasoning, a gap of sufficient length

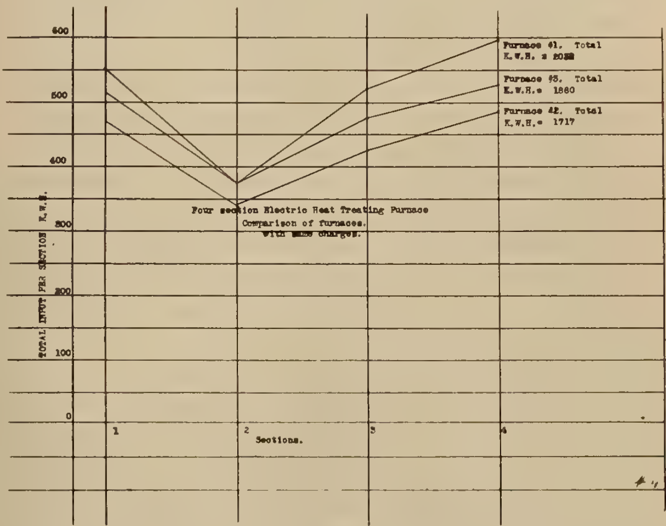


FIG. 13. COMPARISON OF FURNACES WITH SAME CHARGES

to afford protection for static electric discharges resulting from electric storms would not necessarily be a proper protection if the circuit were hit by a "lightning bolt."

There would seem to be need of still greater precautions than are suggested in the following paragraph from Technical Paper 108, Bureau of Mines:

"A suitable gap may be provided by inserting in each side of the circuit, near the bottom of the shaft or the slope, or about 100 feet in by from the mouth of the drift, a flexible conductor about 6 feet long. Each of these conductors can be permanently joined to the end of one of the solid incoming conductors and the other end of each flexible conductor can be provided with a lug for fastening to one of a pair of screw studs in which the outcoming solid conductors should terminate. A similar pair of dummy studs should be installed 6 feet distant from the live studs so as to provide a place for fastening the flexible conductors out of circuit. The dummy studs should be provided with a locked clamp or similar device for locking the flexible conductors out of circuit."

It might be feasible to so arrange a firing circuit that the incoming lines could be connected to a high resistance ground at the same time a gap was made in the circuit. Such a ground would tend to dissipate extraordinary discharges and to prevent such discharges from bridging or jumping the gap in the firing lines.

Again, it might be possible to so arrange the ground, the gap and the direction of the incoming and outgoing shot-firing lines with reference to the gap that the direction of the circuit to the ground is a straight line, while the direction of the circuit through the outgoing lines trough the gap makes a right angle turn. Since lightning tends to follow straight lines this arrangement would probably be an added safeguard.

Finally, care should be taken that all metallic circuits, such as pipe lines of other power circuits entering the mine, are kept at a proper distance from shot-firing lines in order that they shall not serve as possible paths for lightning discharge. If such precautions are not taken it is conceivable that a lightning discharge in a mine through a metallic circuit which is close to a shot-firing line may be partly discharged to the shot-firing lines at a point beyond the lightning gap.—U. S. Bureau of Mines, Reports of Investigations.

Geometrical Form of Rivers*

New Light on the Design of Spur Dikes

THE theory of the free flow of rivers in changing beds seems now fairly established, at least in regard to a few of its parts. The shape of the bed is one of these. In France this theory has received a decisive impulse through the work done by L. Fargue, Inspector General of Bridges and Highways, at the beginning of the last quarter of the 20th century. It is true that even before that time the influence exerted by the shape of the bed, both in plan and in profile, on its depth had been recognized. But it is impossible to find in what had previously been published a general theory for the determination of the best design.

Mr. Fargue's work has been carried on by many other engineers, of which we shall only name Mr. Girardon, whose report, presented in 1894 before the Navigation Congress at the Hague, marks a decisive step forward in the solution of the problem. This report shows in what measure it is possible to apply in practice Mr. Fargue's theory to water streams, as they occur in nature.

All these investigations have led to the fixing of a standard limit-form which rivers with changing beds must approach as closely as possible in order to possess stability, navigable depth and to be able to take care of floods. These conditions are by no means irreconcilable. The first to be considered is stability, without which the others could not obtain. The following gives the definition of this standard type, in geometrical form, as it were.

In the accompanying diagram Fig. 1, the contour lines[1] at the low water bank, marked elevation 0, follow continuous curves resembling the Sine Curve. At one and the same bank they change from concave to convex, and vice versa, the opposite bank going through the same changes in reverse sequence, for the same cross sections taken at right angles to the center line of the channel. The distance between the two curves undergoes a slight periodical variation. They diverge from the point of inflection toward the apex. The distance between them further increases continuously, in a still lesser degree, as they proceed down stream.

These lines are the directrices of, so to speak, ruled surfaces, whose generating lines, at right angle to the directrices, flatten out more and more as they approach the apices of the convexities, and on the other hand become more erect between the points of inflection and the apices of the concavities.

The curved line of intersection of these two surfaces, each belonging to one of the banks, is the center line of the channel. In plan this curve clearly runs close to the concavities and crosses the center line between low water banks, passing from one to the other.

The contour lines, or lines of surface filaments thus generated, also resemble the Sine Curve and are similar to the directrices taken at the low water banks. In horizontal projection they converge at the concave banks and diverge at the convex banks. Lines of same elevation on each bank converge, the more closely the lower this elevation. Near the point of inflection they come in contact at the center line of the bed. The curves of lower elevation than the contact lines close and form crescent shaped pockets at the concavities.

Above the directrices chosen (low water banks) the generating lines increase in length by an increment continuously decreasing as one proceeds from the convex to the concave apex. The locus of the extreme end of these generating lines is the foot of the river bank, consisting of a rather steep slope which limits the river bed, generally in a firmer part of the soil. Proceeding from a convexity to a concavity this slope—one bank only being considered at a time—converges toward the directrix, and its height may vary between the extreme limits of zero to the height of the valley level above the low water bank. The slopes of the two opposite banks run gradually farther apart as one proceeds from the points of inflection toward the apices, for the reason that the width gained at the convex bank is greater than the width lost on the concave side.

Mr. Fargue in his two essays published in the Annales des Ponts et Chausseés[2] has indicated the numeric proportions which these elements must satisfy in order to produce best results. In first place they establish the relation of the width at the points of inflection to the width at the apices, and of these widths to the distance from points of inflection to the apices, and finally, of these distances to the angles enclosed between the tangents at two consecutive points of inflection. It is needless to give here all these data. Suffice to say that they have been computed, that they are theoretically interesting and that it would be worth while to confirm them by calculations based on the principles of hydraulics. For Mr. Fargue has deduced them from observations only, and these have been limited in number. They are, however, sufficient to establish the fact that there is an ideal best type, and further to establish the general aspect of this type.

It would be difficult to recognize in this geometric picture a river in its natural or even considerably regulated state. The resemblance is about as close as that of a mountain peak and a pyramid or a cone. This, however, is the inevitable shortcoming of any attempt to represent by means of geometry or calculation objects and phenomena as they occur in nature. Nevertheless, in many cases even such imperfect representations are useful. The conception of a standard type, geometrically defined, may serve as a guide for the regulation of a river, although the latter could never be made to resemble it very closly.

In fact if we examine the various regulation systems proposed or executed since the above theory was formulated, we shall find that all of them, implicity or explicitly, are nothing more than the application of the appropriate means to make the stream under consideration resemble as closely as possible the standard type, as seen by the designer. However, as it is impossible in the majority of the cases to obtain this result for the whole of the river, the regulation is attempted in sections only and often limited to the crossings at the points of inflection. One of the main points of Mr. Girardon's report is precisely the stating of this very fact.

The means of attaining the desired form are many. Mr. Fargue seems to admit that by fixing the banks, especially the concave bank, according to an appropriate design, the standard form will automatically be realized. He supports this statement with favorable examples, but we believe these to be due to fortunate circumstances, first among these the fact that the course of the center line, in plan, varies little from the theoretical course, especially so in regard to the distances between apices of the curves and their relation to the angles they enclose. When, as this is the case for the Seine River, these distances are excessive and include long straight alignments their design presents peculiar problems and the construction of high dikes is not sufficient for their regulation, except where a narrowing of the bed is useful.

Some time the directrix (line of the low water bank) or a neighboring water line is fixed instead of the high river bank. This is the system of the low training dikes.

High dikes and low dikes used separately having sometimes proved insufficient, they have been combined, fixing the form of the bed by two directrices on each bank.

Again, along another line of thought, generating lines of

[1]Upon a sufficiently reduced length, these two kinds of curves, which differ in principle, because of the slope, practically merge.

[2]Fasc. II, 1903: Form of the Bed of Navigable Rivers. and fasc. III, 1907: Equations of the Empirical Laws of Fluvial Hydraulics (both in French).

the standard form have been fixed instead of directrices. This is the system of the dipping spur dikes, submerged dikes, etc., as applied on the Rhône River.

Both systems, longitudinal and cross dikes, have been combined in various ways on the Rhône and later on the Loire. On the Rhône T-shaped dikes have been built which are elements of generating lines combined with elements of low directrices. On the Seine spur dikes were attached to high dikes, or a high dike was connected to a low dike by a few cross dikes. In short parts of the two groups which we just have outlined were fixed in a haphazard way, without a well defined plan and therefore without the necessary elements of success.

Approached with this broader view, the study of the regulation opens a vista on new variations.

Why limit to two the number of dikes, high dike and low dike (Fig. 2) and thus substitute for the normally gentle slope of the convex bank two very high steps? Would it not be more natural to multiply the number of steps and follow more closely the straight course of the generating line? Where conditions favor the formation of deposits back of each elementary dike this system has the advantage of great saving in material (Fig. 3). Dikes arranged in successive steps would follow the horizontal projection of the stream lines. They would have their maximum spacing at the apex of the convexities and converge gradually so as to unite in one single dike at the apex of the concavities. The banks would be ascended in steps like stairs in a house.

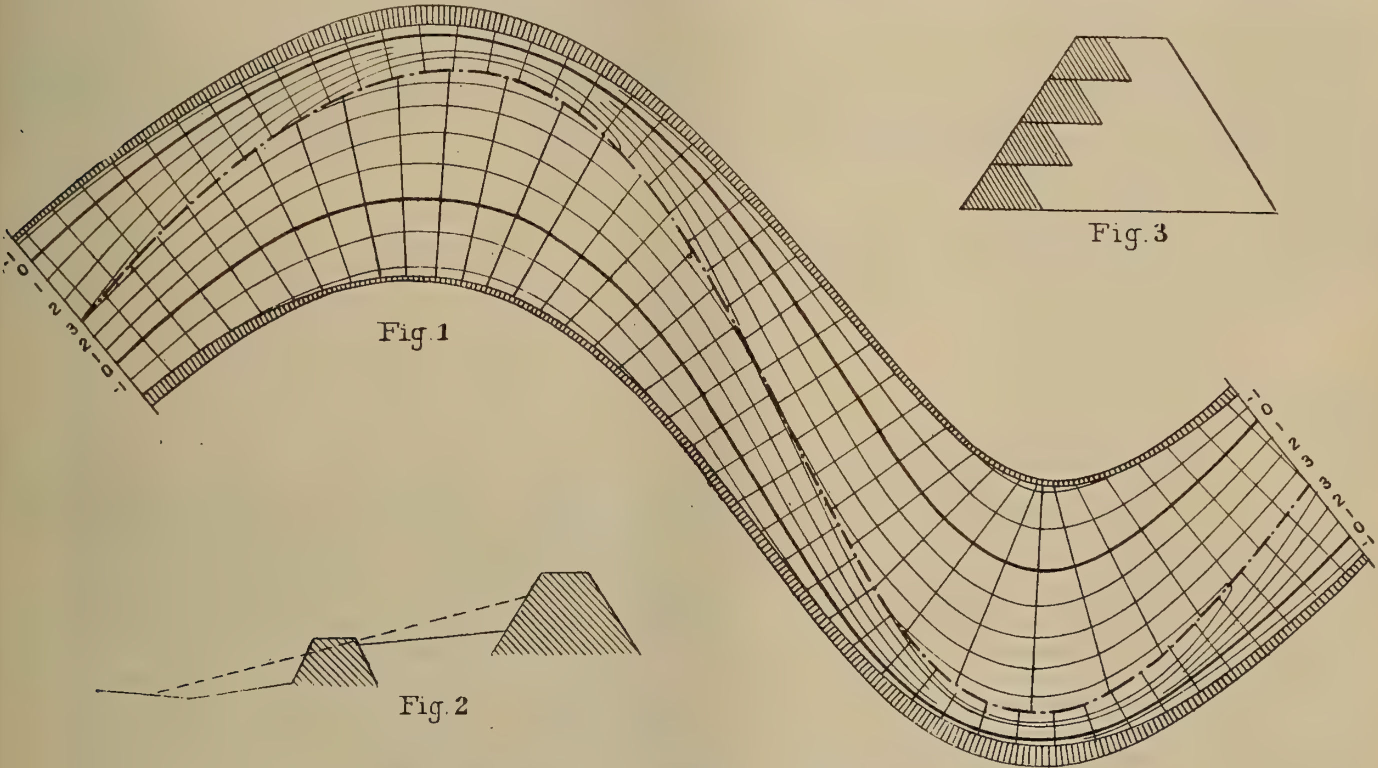


Fig. 1

Fig. 3

Fig. 2

IDEAL GEOMETRICAL FORM OF A STREAM OF WATER

Nothing would prevent the crossing of the longitudinal dikes by cross dikes dropping from the elevation of one to that of another and being arranged like cross hatching on a topographical map between contour lines.

The number of possible combinations is unlimited. Once the principle from which they are derived is well understood they present themselves to the imagination. Therefore we shall, in conclusion, only insist on this principle. Properly to design the regulation of a portion of a river it is well to have in mind the scheme of the normal shape of its bed and its decomposition into curved directrices and straight generating lines. The regulation will consist in the creation of a skeleton made up of directrices and generating lines, resembling as closely as possible the standard form and arranged in such a way as to fill out with silt deposits following this form, and to reduce the necessary construction work to a minimum.

RESISTANCE TO DECAY NOW A FACTOR IN CHOICE OF AIRPLANE WOOD.

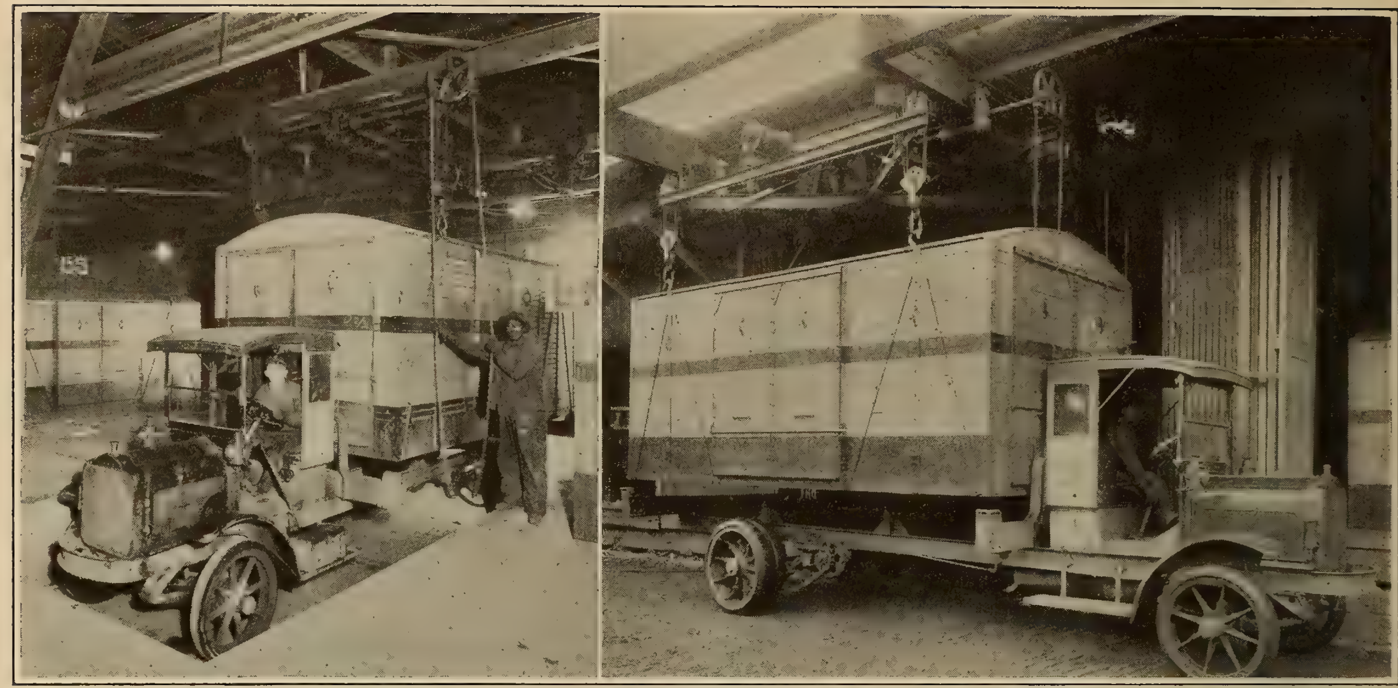
Airplanes in the past have been so short-lived that it has mattered little whether the wood in them was resistant to decay or not. Now with better construction and less accidental breakage of airplane parts, instances are coming to the attention of the Forest Products Laboratory of parts needing replacement because of decay.

The fact is being recognized that many woods in common use for airplanes are not resistant to decay and may be destroyed very rapidly when exposed to unfavorable weather conditions.

Fortunately, there are woods whose value in aircraft has been demonstrated which are highly durable. Among these perhaps the most notable is Port Orford cedar. Two others which in tests made by the laboratory have proved very resistant to decay are southern cypress and California redwood. Douglas fir, white oak, and black walnut stand fairly high in durability. Mahogany and Spanish cedar are reputed to be very durable, but no tests have been made on them in the United States. Spruce, which has been the favorite wood for aircraft, is, unfortunately, appreciably less durable than any of the species mentioned. Likewise basswood, beech, birch, and maple may be classed with the less durable species.

The sapwood of practically all species decays readily. Hence in selecting wood for durability, only the heartwood should be accepted.

In cases where it is not practicable to use a naturally durable wood, the life of the wood part may be prolonged by giving it a preservative treatment. Sodium fluoride is a preservative which may be successfully used on parts that are to be glued. Coal-tar creosote, where its color and odor would not be objectionable, may be used for parts that are not to be glued. Decay in struts, propellers and some other large members can be prevented by applying a coating of aluminum leaf. This keeps the wood dry and dry wood does not decay.



TROLLEY FOR CONVEYING DEMOUNTABLE BODY TO A TRUCK CHASSIS (LEFT) AND REMOVING THE BODY FROM THE TRUCK (RIGHT)

Motorizing Railroad Terminals*

The Use of Motor Trucks to Release Box Cars Held Up at Freight Yards

By B. F. Fitch

FOR years trucks have been proven valuable transportation mediums, but their adoption and scientific operation has been ignored by railroads whose business was primarily transportation. This was possibly due to the fear of competing service similar to the old theory a couple of decades ago that interurban lines would detract from railroad earnings.

The ingredients to be considered in transportation cost estimates are tons, miles and minutes, and, generally speaking, the greater number of tons and miles, crowded into the smallest number of minutes, the lower the transportation cost.

Every unit of transportation from wheel-barrows to gondolas is valuable when allotted exclusively to the service it is best fitted to discharge. A team can successfully haul 75 ton-miles and a motor truck 500 ton-miles in a ten-hour working day. Compare this with railroad performance in which the average box car movement is but 25 miles per day. If loaded with merchandise to but a ten-ton average, it discharges but 225 ton-miles in a 24-hour day. It is therefore, obvious that box cars suffer a handicap.

Freight house operating practice demands that box cars lie idle ten hours a day. If utilized exclusively for transportation and kept continuously moving for the remaining fourteen hours, even at an average speed of but twenty miles per hour with ten-ton loads, the potential possibility of each freight car is 2,800 ton-miles daily.

There is practically no limit to what the rails will carry, if cars, when consolidated in trains, are at once started and kept continuously moving; therefore, it is logical to charge inadequate terminal facilities with the major portion of the box car's tonnage deficiencies. Inadequate terminals alone are not responsible for this nor can either the railroads or the public be censured for illegitimately using box cars in lieu of other facilities for short term storage. These are influences detrimental to box car efficiency, but without terminals, necessary evils.

The prime trouble is that, as an operating necessity, in absence of other facilities, box cars have been assigned to a service for which they were never originally intended, and this make-shift usage has complicated switching interchanges at all terminal points to the detriment of high mileage efficiency of all cars.

Our national transportation practice and trade influences of the traffic do not permit of any radical terminal changes. Any revolutionary attempts along this line might embarrass our production resources as greatly as a change in the monetary basis. Therefore, evolutionary improvements only can be considered.

Refinements of present rail practice and additional facilities will occur, but rail transportation cannot be greatly improved because locomotives are now practically up to the safety limits of rails and bridges and without increasing weight of locomotives, draw bar efficiency cannot be increased, and without an increase in draw bar efficiency transportation costs cannot be lowered. Thus, obviously the field for improvement is terminals.

To demonstrate the fact that railroad transportation has outgrown railroad terminals, it is interesting to note that from outer classification yards to pier station delivery at New York the cost to carrier is not less than \$3.50 per ton and, similarly, at Philadelphia not less than \$2.50 per ton, or a joint terminal cost of \$6 per ton. Whereas, the main line haul between these two terminals, if estimated at a maximum cost of 6 mills per ton-mile, suggests a transportation cost of 60 cents versus terminal costs of \$6. Chicago is no better off than Philadelphia and the haul is about ten times as long; hence, joint terminal cost is as great as the transportation or rail haul cost from Chicago to New York.

After five years of terminal studies, inspecting innumerable stations built over fifty years ago which are still the intakes and outlets of our great transportation systems, using the recognized best equipment in the world, no wonder the subject of terminals is a topic of nation-wide discussion and, naturally, all with creative brains are offering solutions.

*Paper read at the convention of the Materials Handling Machinery Manufacturers' Association, New York, Feb. 26, 1920.

With unlimited financial resources the engineering talent of this country can quickly solve the problem. Ideal joint terminals at a cost of $50,000,000 to $500,000,000 are possible in all of our principal centers, but present chaotic conditions considered who will assume the responsibility of such abnormal financing? Even if offered opportunity to avail themselves of such the railroads would have to scrap present huge investments and the scrapping of these investments at any industrial center will disrupt realty values possibly to financial ruin of innumerable manufacturing plants built in suburban localities on the theory that the inducement which warranted the building would afford perpetual service.

For this reason each present terminal layout must be continued substantially as at present. Conservatism recommends no radical changes, but demands revolutionary changes to better conditions for both carriers and shippers.

Every city in the country has its labyrinth of rails, team tracks, private sidings, obsolete main freight stations and substations, between all of which box cars are shuffled or switched around, like cards in a solitaire deck, in the performance of a duty for which the cars were never designed.

The innumerable switch cut movements of such cars confiscates capacity of the rails and the cost of handling these cars over rails, to detriment of through traffic, is primarily responsible for excessive terminal expense.

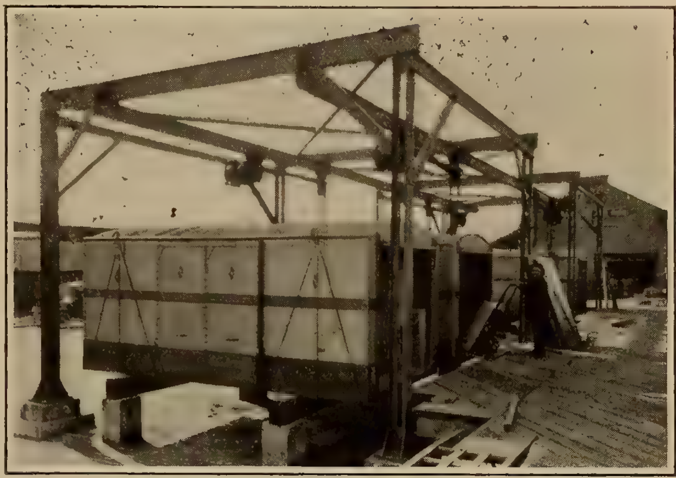
If all the large cities in the country could be furnished with ideal scientifically designed and mechanically operated freight houses, there is no question of accruing economies both in terminal practice and transportation costs, because the railroads then would enjoy a one point make-up and a one point break of all freight cars. The result would be loading of cars to weight or displacement capacity for uninterrupted direct movement to other terminals. This consolidated loading would naturally decrease the number of cars now dispatched from a plurality of stations within any one city to the existing plurality of stations in all other cities.

DEMOUNTABLE BODIES BEING LOADED AT THE FREIGHT HOUSE OF THE LOUISVILLE & NASHVILLE RAILROAD AT CINCINNATI

Despite this opportunity, even if attainable, the industrial trap car and the intro-terminal trap car will apparently always complicate terminal interchanges to detriment of switching refinements. Terminal operating economies will be in direct ratio with the decrease in the number of interchange switching combinations. So apparently new freight stations at huge investment are no guarantee of great reductions in terminal expense, because freight station labor cost is but a small item as compared with total terminal expense.

Between all the widely distributed freight houses of the various railroads in each and every terminal, box cars are used in transfer or connecting line service. When so used, they are in various sections termed "trap," "transfer" or "ferry" cars. For instance, in any city with seven non-competing railroads radiating to different sections, each line receives daily in its city cars some freight for each of the city connections. Numerically this means 42 cars in transit to and 42 cars in transit from, a total of 84 cars. But due to yard interchange delays these cars average a third day arrival instead of a second day arrival; hence, 252 cars are assigned daily to such service. Thus 75,600 car days are required annually.

Industrial expansion at any city with seven initial lines,



SUB-STATION OF THE BALTIMORE & OHIO RAILROAD, CINCINNATI, SHOWING DEMOUNTABLE BODIES BEING LOADED AND UNLOADED

has, as a rule, outgrown station facilities and railroads for economy's sake have strategically established sub-stations along their rights-or-way as traffic influences for shipments from outlying districts. Since all the freight from these outlying districts has to be brought to main stations to be consolidated in cars for dispatch from such main stations to destination points, and since all of the freight for these sub-stations comes out of main station cars on arrival, trap cars are necessary in this main sub-station service of each line. The number of cars so used is a multiple of stations. If, as above stated, each of the seven lines has three stations, 42 cars are required, movement delays to which are as great as connecting line cars; therefore, the wasting of an additional 37,800 car days. This explains one of the reasons for car shortage and an operating abuse which has been obsoleted by the success of a motor terminals installation at Cincinnati, Ohio.

Briefly, this installation consists of overhead rails, electric cranes, electric hoists, motor trucks and a plurality of interchangeable motor truck bodies. The system of operation requires an empty body for each station movement demand of railroad on its inbound main station platform. At the larger stations there are several locations for such body settings, thereby decreasing the trucking distance for freight. As the freight comes from the cars, it is trucked to the nearest location containing a body carded for any connection or any sub-station.

When loaded, these bodies are sealed and under telephone order of a joint dispatcher, employed by the railroads, mechanically loaded upon trucks and thus routed over city's streets to connection.

On arrival at outbound platform of the connecting line, the body is mechanically removed and an empty body, previously unloaded, is similarly put upon motor truck chassis for delivery to inbound platform of that house, where the operation is repeated and another loaded body forwarded in the same manner to some other freight house.

If the load happens to be to a sub-station, it remains on

platform until dispatcher is advised by agent at sub-station that return load is available. Then the loaded body of inbound freight to that substation is forwarded and the motor truck exchanges same for the previously reported load of outbound freight to be delivered at main station, where it is consolidated with other city freight in line cars made up daily to innumerable other destination points.

From the above it is evident that all freight, except possibly the portion arriving during the last hour of station operating day, whether between main and sub-stations or between main stations of the various railroads, is currently loaded and out of the terminal. Previously this freight by trap cars suffered an average three days' delay and the shuttle movement of these individual cars over terminal rails interfered with the group movement of complete cuts of station cars. Hence, the congestion which previously made Cincinnati notorious as a check-valve in rail routings.

In May, 1917, the Big Four Railroad permitted a test installation between its five main and sub-stations. The innovation was an early success, but the other roads were skeptical of its enduring efficiency. In the early months of 1918 a special committee was appointed to analyze the entire terminal and, based upon Big Four accomplishments, recommend what economies and benefits could be anticipated from completely motorizing Cincinnati's terminal.

The summary of this comparative report prophesied the following, and as a result contracts were negotiated:

Annual economy, $61,652.96;

Advance movement of freight 52.4 hours;

Increase inbound platform floor area 14.8 per cent;

Increase outbound platform floor area in ratio with station operation;

Increase main station trackage 21.4 per cent;

Increase main station realty 122,660 square feet;

Release 66,862.5 cars for line service per annum;

Extension of present labor, 30.4 per cent;

Eliminating the rehandling of 86,976 tons of freight, lessens railroads' liability of loss and damage.

In 1919 equipment orders were entered and railroads commenced station changes and superstructure construction. The terminal is not fully equipped, for both the railroads and the Cincinnati Motor Terminals Company which is operating this equipment on contract basis for the railroads, has suffered exasperating delays. However, in recent analyses of accomplishments it is proven that, owing to increased operating costs of railroads the prophesied 17.1 cents per ton economy is in practice actually a saving of 35.2 cents per ton, making the annual economies $126,507.75 instead of $61,652.46.

This service has proven that all widely distributed station facilities can be laced up as a unit without investment cost to the railroads, thereby giving to each and every terminal the benefits of a union freight station. The rates paid for the service are less than what interest charges alone would be on the cost of constructing a consolidated terminal. The operating program of railroads and the established perquisites of shippers are in no wise disturbed, but the railroads at large through the influence of this current versus their past interrupted movements enjoy an increase of terminal rail, station rail, and station platform facilities. This increase can be perpetually extended at minimum investment, in ratio with increasing tonnage demands, which naturally will accrue at any industrial city enjoying better shipping facilities.

Extensions are now possible in the form of rail sub-stations or off-track warehouse sub-stations by this system, and can be gradually provided when tonnage demands warrant. There is no necessity to finance elaborate facilities to take care of accruing demands which may not develop for fifty years.

What has been done at Cincinnati can be adapted to the varying demands of all principal terminal cities. In some the connecting line trap car predominates as the greatest detriment to successful terminal operation; in others the substation trap car.

The flexible possibilities of trucks are now clearly defined for industries whose transportation facilities are dependent upon rail extensions. Opportunities at each point are limited only to intelligent installations following detail analysis to establish the greatest terminal deficiencies of carrier to meet shipping demands of the public.

Acomplishments at Cincinnati warrant idealistic theories of the system as applied to the greatest terminal problem in the world. New York is that problem, for as the established principal port of this country, our industrial expansion is restricted by New York's lack of port facilities, unless, as will ultimately happen, the nation at large refuses longer to suffer by reason of New York's conservatism and creates other trans-shipments ports.

At present the railroads monopolize approximately 30 per cent of Manhattan's piers for freight stations. To expand the port these piers are indispensable for coastwise and overseas steamers. Where not individually owned, the rental value of piers is out of all proportion with freight tariff returns.

A few blocks inland, realty enjoys but a fraction of bulkhead rental values. If inland joint stations in say 12 zones were constructed on this otherwise comparatively non-productive realty, the railroad piers could be released for shipping and station facilities be attained by the railroads at practically no cost, because of increased rentals possible from warehouses and industrial floors above joint freight terminals.

If all roads contributing this terminal had transfer stations at their rail bulkheads or a few blocks back from the Jersey, Staten Island and Bronx valuable waterfront, carload and less carload package freight could be immediately transferred from cars to motor truck bodies, which would be designated for each of these inland stations, and the freight cars thereby released for immediate reloading of outbound freight. The number of bodies assigned each zone station would be sufficient to meet the tonnage demands.

These bodies when loaded on trucks, would be routed over streets to nearest available Staten Island or Jersey slip for ferrying to Manhattan slip nearest inland station destination and vice versa on return movement. Until they were proven inadequate, public ferries could be used.

If we add to the generally admitted $3.50 terminal cost to carriers the established minimum cartage cost of $2.50 per ton to shippers, the joint terminal cost at New York is $6.00. Under normal conditions approximately 30,000 tons daily moves from State Island and Jersey to Manhattan and 20,000 tons daily from Manhattan to Staten Island and Jersey on outbound movement, a total of 50,000 tons daily, which at the above cited $6.00 joint cost is an item of $300,000 per day.

For the railroads alone at Cincinnati the interchange is furnished by the Cincinnati Motor Terminals Company between stations within a ten-mile zone at rates averaging less than $1.00 per ton. The minimum is 80 cents and the maximum $1.25. If trucks moved by short ferry routes (at no operating cost in ferry transit other than ferry tariffs) no hauls from rail bulkhead transfer platforms to inland stations could exceed ten miles.

It is impossible to prophesy what rates for this interchange can be established, but they would certainly not be over $2.00 per ton. Owing to the short haul afforded shippers by these inland stations and the unlimited tail gate space, which they would enjoy at such, the cost to shippers could not average over $1.00 per ton. Hence it is logical to infer a joint net saving of $3.00 per ton is possible for 50,000 tons daily, an annual item of $45,000,000. No wonder the high cost of living on Manhattan! But one year's savings will more than cover the entire necessary outlay if the cost of inland stations is not considered.

The inland station investment is a realty venture requiring no financing on the part of the railroads, because assured rental returns from upper stories will invite outside capital to furnish the station facilities in ever increasing numbers as fast as the railroads desire to contract for the use of such.

The Last Stand of the Reciprocating Steam Engine*

Startling Picture of the Inefficiency of the Steam Locomotive

By A. H. Armstrong

DURING the year 1920 the people of the United States will pay out for automobiles, not commercial trucks nor farm tractors, but pleasure vehicles, a sum of money considerably greater than the estimated requirements of our steam railways for that year. The railways, however, may find it very difficult and perhaps impossible to secure the large sums needed without government aid, notwithstanding the fact that the continued operation and expansion of our roads is of vital necessity to the welfare and prosperity of the country and all its industries. The will of the American public has always been constructive and undoubtedly, in due time, its voice will be heard and properly interpreted by its representatives in Washington with the resulting enactment of such laws as will permit our railways again to offer an attractive field for the investment of private capital.

The purpose of this paper is not to discuss the politics of the situation nor any necessary increase in freight rates that may be required to make our roads self-sustaining, but rather to offer certain suggestions as to the best manner of spending the sums that must ultimately be provided for new construction and replacements.

During the war period many lessons have been most clearly brought home to us and not the least of these is that there is something inherently wrong with our steam railroads. During the three generations of its development, we have become accustomed to look upon the steam engine as properly belonging to the railway picture and have given little thought to its wastefulness and limitations. It is around the steam locomotive that railway practice of today has gradually crystallized.

During the winter of 1917-18 our railways fell down badly when the need for them was the greatest in their history. It is true that the cold weather conditions were unprecedented and the volume of traffic abnormal, but the weaknesses of steam engine haulage were disclosed in a most startling and disastrous manner. Delayed passenger trains in cold weather can be endured by the traveling public in suffering silence or voluble expression, according to temperament; but the blocking of our tracks with frozen engines and trains, resulting in a serious reduction of tonnage in cold weather and a prohibitive delay in transportation of freight in times of great stress, is quite another thing and plainly indicates the inability of the steam engine to meet overloads and adverse climatic conditions.

In marked contrast to the adjoining steam engine divisions, the 440-mile electrified section of the Chicago, Milwaukee and St. Paul Railway continued to do business as usual all through that trying winter of 1917-18. The electric locomotives brought both freight and passenger trains over the electrified tracks in schedule time or better; in fact, it was quite customary to make up on the 440-mile electric run fully two hours of the time lost by passenger trains on adjoining steam engine divisions. While the results obtained upon the Chicago, Milwaukee & St. Paul were perhaps more spectacular due to the greater mileage electrically equipped, other electrified roads contributed similarly attractive records. The reliability and permanency of the comparison between steam and electric locomotive haulage is sufficiently guaranteed, therefore, by the results of several years' operation, to justify drawing certain conclusions regarding the merits of the two types of motive power. The following analysis of the railway situation is therefore offered for the purpose of exposing the fact that railroading today is in reality steam engine railroading and the general introduction of the electric locomotive will permit of fundamental and far reaching changes in the method and cost of hauling freight and passenger trains.

The writer is not proposing the immediate electrification of all the railways in the United States, as many roads of lean tonnage would render no adequate return upon the large capital investment required, but is offering the following table of total operating statistics simply as a measure of the magnitude of the problem confronting us in the future. In this country it should be noted, however, that we have during the past thirty years installed electric power stations equal to twice the estimated capacity required for the electrical operation of every mile of our tracks today.

TABLE I—TOTAL TON-MILE MOVEMENT ALL RAILWAYS IN UNITED STATES—YEAR 1918.

	Per Cent	Ton Miles
1—Miscellaneous freight cars and contents	42.3	515,000,000,000
2—Revenue coal cars and contents	16.23	197,000,000,000
3—Locomotive revenue, driver wt. only	10.90	132,300,000,000
4—Passenger cars, all classes	16.13	196,000,000,000
Total revenue, freight and passenger	85.56	1,040,300,000,000
5—Railway coal	5.00	60,600,000,000
6—Tenders, all classes	6.50	78,800,000,000
7—Locomotive railway coal	0.39	4,700,000,000
8—Locomotive, non-driving wt.	2.55	31,000,000,000
Total non-revenue	14.44	175,100,000,000
GRAND TOTAL (All classes)	100	1,215,400,000,000

The tonnage passing over the tracks of our railways may be subdivided in a most interesting manner as shown in Table I. The first four items, representing 85.56 per cent of the total ton-miles made during the year 1918, may be regarded as fundamentally common to both steam and electric operation. By introducing the electric locomotive, however, the last four items are reduced to the extent of completely eliminating items (6) and (7), reducing item (5) by possibly 80 per cent and item (8) by one-half. Of the total of 14.44 per cent affected, therefore, it may be assumed for purposes of comparison that approximately 12 per cent or 146,000,000,000 ton-miles at present hauled by steam engines over our roads will be totally eliminated with electric locomotive haulage. This ton-mileage eliminated is equal to over 20 per cent of items (1) and (2) representing the revenue producing freight traffic on our railways. In other words, if all our railways were completely electrified they could carry one-fifth more revenue producing freight tonnage with no change in present operating expenses or track congestion.

It is evident that the greater part of the tonnage reduction effected by electrification is included in items (5) and (6), representing the railway coal movement in cars and engine tenders. The steam engine tender will of course entirely disappear, while the railway coal haulage will be largely curtailed by utilization of water as a source of power and the establishment of steam power houses as near the coal mines as an abundant supply of good condensing water and load demand will permit. While water power should be utilized to the fullest economical extent, the greater portion of the railway power must undoubtedly be supplied by coal, due to the unequal geographical distribution of water power available.

Even with coal as the source of power, it may not be fully appreciated just how enormous is the saving made by burning fuel in large modern power stations under the most efficient conditions possible, instead of under the boilers of 63,000 en-

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gines which by necessity must be designed and operated for service rather than for fuel economy. During the year 1918 the fuel used by railways is reported to be as shown in Table II.

TABLE II—RAILWAY FUEL 1918.

Total coal production (all grades)	678,211,000 tons
Used by steam railways	163,000,000 tons
Percentage of total	24 per cent
Total oil marketed in U. S.	355,927,000 bbl.
Used by steam railways	45,700,000 bbl.
Percentage of total	5.8 per cent
Coal equivalent of oil at 3½ bbl.	13,000,000 tons
Total equivalent railway coal	176,000,000 tons

A quarter of all the coal mined in the United States is consumed on our railways and the following analysis will point out some features of this extreme wastefulness which are inseparable from steam engine operation.

During the year 1910, exhaustive tests were made upon the Rocky Mountain Division of the C., M. & St. P. Ry. to determine the relation existing between the horse-power-hours work done in moving trains and the coal and water consumed on the steam engines in service. Table III gives the results of these tests:

TABLE III—C., M. & ST. P. RY.; ROCKY MOUNTAIN DIVISION. COAL AND WATER USED.

	Water per H.p.-hr.	Water per Lb. Coal	Coal per H.p.-Hr.
Three Forks-Piedmont	39.6	5.08	7.75
Piedmont-Donald	35.4	4.70	7.54
Deer Lodge-Butte	39.7	4.85	8.31
Butte-Donald	40.4	4.86	8.74
Harlowton-Janny	38.0	4.09	8.90
Janny-Summit	44.2	4.65	9.48
Three Forks-Piedmont	41.4	6.51	6.37
Piedmont-Donald	40.2	5.63	5.78
Average of eight tests	39.86	5.04	7.86

The records were obtained during the portion of the runs that the engines were doing useful work in overcoming train and grade resistance, that is, all standby losses were excluded. The through run, however, included such losses in the magnitude shown in Table IV:

TABLE IV—STANDBY LOSSES.

	Coal per hour
Fire banked in roundhouse	150 lb.
Cleaning fires for starting	800 lb.
Coasting down grade	950 lb.
Standing on passing track	500 lb.

Adding standby losses to the average of 7.86 lb. per h.p.-hr. obtained in the preceding eight tests, the total actual coal consumed under the engine boiler in twenty-four hours divided by the actual work performed by the engine is found to be 10.18 lb. per h.p.-hr, at the driver rims.

As the result of this particular series of tests it was determined that the coal consumed while doing useful work was raised 30 per cent by standby losses. It should be appreciated in this connection moreover that this value was obtained on through runs with no yard switching service or adverse climatic conditions. It may be concluded therefore, that under all conditions of service fully one-third the coal burned on our steam engines today is absolutely wasted in standby losses of the general nature indicated above.

Supplementing these tests, a 30-day record was kept of all coal used on the entire Rocky Mountain Division and the total engine, tender, and train movements reduced to horse-power hours, resulting in a value of 10.53 lb. coal consumed per horse-power-hour at the driver rims. Both the above values were based upon constants of 6 lb. per ton train resistance at all speeds and 0.7 lb. per ton per degree of curvature as determined in part by dynamometer car tests and representative of general railway operation. Reducing the average coal values of the test runs and the 30-day record per horse-power-hour to electrical constants, we arrive at the data shown in Table V:

TABLE V—COAL EQUIVALENT PER KW-HR.; STEAM OPERATION.

Coal per h.p.-hr. at driver rims	10.27 lb.
Coal per kw-hr. at driver rims	13.75 lb.
Coal per kw-hr. at power supply on basis 55 per cent efficiency	7.56 lb.

It is this last figure of 7.56 lb. of coal burned on steam engines to get the equivalent tonnage movement of one kilowatt-hour delivered from an electric power station that is of special interest to this discussion. Comparing coal and electrical records on the Butte, Anaconda & Pacific Railway before and after electrification results in arriving at a value of 7.17 lb. of coal previously burned on the steam engines to equal the same service now performed by one kilowatt-hour input at the substations, a figure comparing favorably with 7.56 lb. above arrived at by an entirely different method.

TABLE VI—ANALYSIS OF ROUNDUP COAL USED.

Fixed carbon	49.26 per cent
Volatile carbon	38.12 per cent
Ash	7.74 per cent
Moisture	4.88 per cent
B.t.u.	11,899

Making due allowance for the fact that roundup coal is somewhat low in heat units, it is nevertheless within the limits of reasonable accuracy to assume that the steam engines operating over all our railways are consuming coal at a rate closely approximating 12.75 lb. per kilowatt-hour of useful work done, as measured at the driver rims or 7 lb. per kilowatt-hour as measured at a power station and including for convenience of comparison the transmission and conversion losses inherent to electrical operation.

An electric kilowatt can be produced for so much less than 7 lb. of coal that we are now in position finally to forecast the approximate extent of the coal economy that would result from electrification.

TABLE VII—RELATION BETWEEN KW-HR. AND TON-MILES, CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY, AVERY-HARLOWTON—YEAR 1918.

	Passenger	Freight
Average weight locomotive	300 ton	284 ton
Locomotive miles, 1918	651,000	1,431,500
Locomotive ton-miles	195,000,000	407,000,000
Trailing ton-miles	434,406,000	2,903,099,000
Total ton-miles	629,406,000	3,310,049,000
Kilowatt-hours	24,890,000	105,287,000
Watthours per ton-mile	39.6	31.9
Ratio locomotive to total	31 per cent	12.3 per cent
Watthours per ton-mile combined movement		33.2
Ratio locomotive to total combined movement		15.25 per cent

All power values in Table VII are given at the point of supply from the Montana Power Company at 100,000 volts and include deductions made for the return of power due to regenerative braking of the electric locomotives on down grades, amounting to approximately 14 per cent of the total. Owing to the excessive rise and fall of the profile of the electrified zone of the C., M. & St. P. Ry., its operation is materially benefited by regenerative electric braking and the value of 32.2 watthours per ton mile for combined and passenger movement should possibly be raised to the round figure of 40 to make it apply more nearly to conditions universally obtaining on more regular profiles.

Hence referring again to the ton-mile values of Table I:

Total ton-miles, 1918	1,215,400,000,000
Watthours ton mile	40
Kw-hr. total movement	48,700,000,000
Coal required at 7 lb. per kw-hr	170,000,000 ton

The actual equivalent coal consumed on our steam railways for the year 1918 is given as 176,000,000 tons, closely approximating the figure of 170,000,000 tons estimated above from the operating results obtained on the C., M. & St. P. electrified zone. These several values check so closely as to justify the completion of the fuel analysis of the railways as shown in Table VIII.

TABLE VIII—COAL SAVING BY ELECTRIFICATION

Total ton-miles steam	1,215,400,000,000
Reduction by electrification	146,000,000,000
Total ton-miles electric	1,069,400,000,000
Kw-hr. electric at 40 watts	42,776,000,000
Coal on basis 2½ lb. per kw-hr.	53,500,000 tons
Equivalent railway coal 1918	176,000,000 tons
Saving by electrification	122,500,000 tons

The startling conclusion arrived at is that approximately 122,500,000 tons of coal, or more than two-thirds the coal now burned in our 63,000 steam engines, would have been saved during the year 1918 had the railways of the United States been completely electrified along lines fully tried out and proved successful today. This vast amount of coal is 50 per cent greater than the pre-war exports of England, and twice the total amount consumed in France for all its railways and industries. Moreover, the estimate is probably too conservative as no allowance has been made for the extensive utilization of water power which can be developed to produce power more cheaply than by coal in many favored localities.

Perhaps no nation can be justly criticized for lavishly using the natural resources with which it may be abundantly provided. In striking contrast with the picture of fuel waste on the railways in this country however is the situation presented in Europe at this writing.

Faced with a staggering war debt, with two millions of its best men gone and an undetermined number incapacitated for hard labor, and with so much reconstruction work to do, France has to contend also with the destruction of half its coal producing capacity. Before the war, France imported twenty-three million of the sixty-five million tons of coal consumed. It is estimated that the full restoration of the coal mines in the Lens region will take ten years to accomplish, which means materially increasing the coal imported into France if pre-war consumption is to be reached, as the relief rendered from the Saar District will not compensate for the loss in productivity of the mines destroyed by the Germans. This situation is being promptly met in part by France in the appointment of a Commission to study the feasibility of the general electrification of all its railways with special reference to immediate construction in districts adjacent to its three large water-power groups, the Alps, the Pyrenees, and the Dordoyne or Central plateau region. It is proposed to electrify 5200 miles of its total of 26,000 miles of railways during a period covering twenty years. If this work is accomplished at a uniform rate of 260 miles a year, it is a most modest program considering the extreme necessity for the improvement.

In even worse plight is Italy with practically no coal of its own and compelled to import its total supply of 9,000,000 tons. The war has brought home to these countries what it means to be dependent upon imported fuel for their very existence and both Italy and Switzerland are also proceeding with extensive plans for railway electrification. Contrary to general understanding, the mines of Belgium are not destroyed, but the need of fuel economy is very acute and this country also has broad plans for railway electrification with immediate construction in view.

Recognizing the many advantages of electric operation of its railways, Europe furthermore considers this a most opportune time to start the change rather than to spend its limited funds in replacing worn out and obsolete steam equipment in kind. Also in marked contrast to the American attitude is the sympathetic interest and constructive assistance rendered by the Governments abroad in regard to the vital matter of rehabilitation of its railway systems. It would not be without precedent if the next decade witnessed England and the Continent outstripping this country in the exploitation of another industry which, while possibly not conceived here, has certainly been more fully developed and perfected in America than elsewhere.

From figures given, the conclusions in Table IX are arrived at in the matter of power station capacity required for complete electrification of the railways in the United States.

TABLE IX—RAILWAY POWER REQUIRED.

Kw-hr. electric operation, 1918	42,776,000,000 kw-hr.
Average load, 100 per cent load-factor	4,875,000 kw.
Power station capacity at 50 per cent load-factor	9,750,000 kw.

It appears therefore that approximately 10,000,000 kw. power station capacity would have been sufficient to run all the railroads for the year 1918, or one-half the station capacity which has been constructed during the past thirty years.

TABLE X—ESTIMATED POWER STATION CAPACITY, UNITED STATES, YEAR 1918.

Central stations	9,000,000 kw.
Electric railways	3,000,000 kw.
Isolated plants	8,000,000 kw.
Total	20,000,000 kw.

In the order of magnitude, therefore, it is not such a formidable problem to consider the matter of power supply for our electrified railways and it becomes evident also that the railway power demand will be secondary to industrial and miscellaneous requirements.

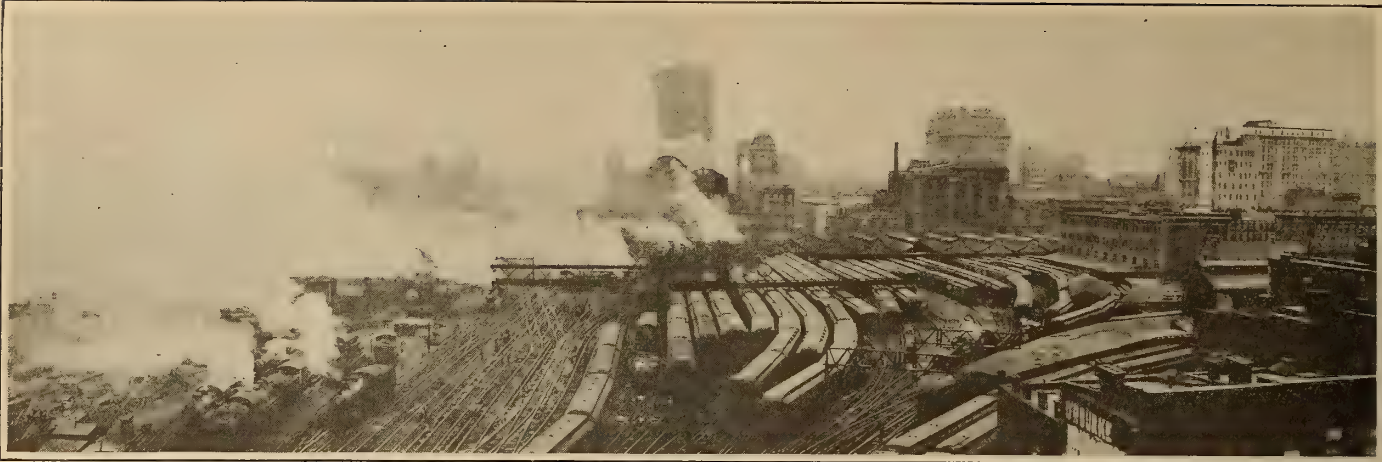
Such being the case, the question of frequency of electric power supply becomes of great importance, if full benefit is to be obtained from extensive interconnected generating and transmission systems covering the entire country. Indeed with the full development of interconnected power systems supplying both railway and industrial load from the same transmission wires, the above assumption of 50 per cent load-factor for the railway load can be materially bettered.

In this connection a method of limiting the troublesome peak load hitherto considered inherent to railway power supply has been in successful operation on the electrified C., M. & St. P. zone for the past year. With unrestrained peaks, the load-factor was approximately 40 per cent, but this low value has been raised to nearly 60 per cent by the installation of an inexpensive and most satisfactory device known as the power limiting and indicating apparatus.

TABLE XI—LOAD-FACTOR RECORDS, C., M. & ST. P. RY.

	Per Cent Duration of Peak	Per Cent Load-Factor
April	6.4	59.3
May	4.6	56.1
June	1.6	56.5
July	0.7	55.6
August	4.1	54.7
September	9.5	58.8

The readings in Table XI cover the performance on the 220 miles of the Rocky Mountain Division supplied by seven substations controlled as a unit. A load-factor of nearly 60 per



SMOKE CONDITIONS AS THEY EXISTED AT THE GRAND CENTRAL TERMINAL, NEW YORK, IN 1906

cent brings the electric railway within the list of desirable customers and makes it possible for power companies to quote attractively low rates for power.

Returning again to the question of power supply, it is instructive to note the general trend toward a higher frequency. It is quite evident that 60 cycles is rapidly becoming the standard frequency in America; and many instances are on record where it has replaced lower frequencies, principally 25 cycles. This fact in no manner handicaps the future development of electric railways, as entirely satisfactory power can be obtained from 60-cycle transmission lines through rotary converters, or synchronous motor-generator sets, depending upon the direct-current trolley voltage desired. Indeed a growing appreciation of the declining importance of 25-cycle power generation in this country contributed largely to the demise of the single-phase system, as its chief claim for recognition is wiped out with the introduction of the motor-generator substations required with 60-cycle supply.

While America apparently has adopted 60 cycles as its standard frequency and can look forward to unlimited interconnection of its large power systems, European practice is evidently crystallizing on 50 cycles. The situation abroad is as yet, however, not clearly defined. In such a small compact country as Switzerland for instance, where so much electrical development is taking place, there is much conflict of frequencies. Apparently there is little appreciation of the advantages resulting from interconnected power stations; in fact the Loetschberg Railway is supplied with power from 15-cycle waterwheel-driven generators placed in the same power station with 42-cycle units supplying industrial load while in the same immediate district there is a 50-cycle transmission line and no tie-in frequency changer sets as yet installed to interconnect any two frequencies. The power company, power consumer, and electrical manufacturer pay heavily for the complication imposed by maintaining three frequencies where only one is needed, and growing appreciation of this fact may lead to the standardization of 50 cycles in Switzerland and thus swing that country in line with its neighbors and ultimately bring about a more economical ratio of installed generator capacity to average load demand for the country as a whole.

A good example of the necessity for improvement in power distribution conditions in Switzerland is provided in the supply of power to the Loetschberg Railway as illustrated in Table XII.

TABLE XII—POWER SUPPLY TO THE LOETSCHBERG RAILWAY, MARCH, 1919.

Total for month	540,180 kw-hr.
Average of six 15 min. peaks	3,489 kw.
Load-factor, basis 24 hours	20.8 per cent

As the railway was operating for only seventeen hours per day, the load-factor during actual operation is somewhat better than 20.8 per cent. On the other hand, the actual momentary peak load greatly exceeded 3489 kw.; and this very fluctuating railway load furnishes a good illustration of the need of combining it with other diversified loads, in order to keep down the fixed investment of power station equipment now set aside for this isolated railway load. For example, the 60 per cent load-factor of the C., M. & St. P. power demand is the ratio of average to momentary peak while the Loetschberg Railway peak load is determined by six 15-min. peaks with momentary peaks greatly in excess of this figure.

Apparently the adoption of a standard frequency of 50 cycles would meet all general requirements in Switzerland, but would necessitate the installation of frequency changing substations to meet the demands for 15-cycle, single phase railway power. If the electrified railways are to benefit, therefore, from the establishment of a common generating and transmission system in Switzerland, the choice of the single-phase railway system might possibly be considered unfortunate, viewed in the light of modern development in power economics and the successful adaptation of the less expensive and more flexible direct-current motor to high trolley voltages.

From the power station standpoint, the electrification of our railways admits but one conclusion. We have some 63,000 engines now in operation and their average combined load amounts to approximately four million horse-power at the driver rims or only an insignificant total of 65 h.p. for each engine owned. It is true that, owing to shopping and for one cause or another, a large proportion of these engines are not in active service at all times, still the average twenty-four-hour output of each engine is less than ten per cent, of its rating. In the case of the C., M. & St. P. electrification, the average load of each individual electric locomotive is only 15 per cent of its continuous rating, but by supplying power to 45 electric locomotives from one transmission system, the average combined load-factor is raised to nearly 60 per cent, a figure which could even be surpassed on roads of more regular profile. Furthermore, when the railway load is merged with the lighting and industrial power of the district and the whole diversified load supplied from the same 60-cycle transmission and generating system, it is quite evident that all the conditions are most favorable for the efficient production of power. In this country such an achievement will probably be governed by the laws of economic return upon the capital required because our vast natural fuel resources are popularly regarded as inexhaustible, but in Europe there is the compelling spur of stern necessity behind the movement to utilize economically the water powers they possess in place of the coal they cannot get.

While the much discussed subject of power generation and transmission is a very vital part of the railway electrification

GRAND CENTRAL TERMINAL FROM 50TH STREET, SHOWING RESULTS OF ELECTRIFICATION

project, chief interest centers in the electric locomotive itself. Few realize what a truly wonderful development has taken place in this connection in a comparatively few years and how peculiarly fitted this type of motive power is to meet the requirements of rail transportation. Free from the limitations of the steam boiler, and possessing in the electric motor the most efficient and flexible known means of transmitting power to the driving axles, the electric locomotive gives promise of revolutionizing present steam railway practice when its capabilities become fully recognized. The only limits placed upon the speed and hauling capacity of a single locomotive are those imposed by track alinement and standard draft rigging. Only questions of cost and expediency control the size of the locomotive that can be built and operated by one man, as there are no mechanical or electrical limitations that have not been brushed aside by careful development. Just what this means in advancing the art of railroading is as yet but faintly grasped, any more than the boldest prophet of twenty years ago could have fully pictured the change that has taken place at the Grand Central Terminal as the result of replacing steam by eelctricity.

Progress in utilizing the capabilities of the electric locomotive has been slow. It is hard to break away from lifelong railway traditions established by costly experience in many cases. In consequence the electric locomotive has thus far simply replaced the steam engine in nearly similar operation. Even under such conditions of only partial fulfillment of its possibilities, the electric locomotive has scored such a signal operating success as to justify giving it the fullest consideration in future railway improvement plans.

On the C., M. & St. P. Ry. 42 electric locomotives have replaced 112 steam engines and are hauling a greater tonnage with reserve capacity for still more. On this and other roads, electrification has set a new standard for reliability and low cost of operation. In fact, although no official figures have yet been published, it is an open secret that the reduction in previous steam operating expenses on the C., M. & St. P. Ry. are sufficient to show an attractive return upon the twelve and a half millions expended for the 440 miles of electrification, without deducting the value of the 112 steam engines released for service elsewhere. As the electric locomotive is destined to leave its deep impression upon the development history of our railways, it is fitting that the remainder of this paper should be devoted to its consideration.

Our steam engine construction is unsymmetrical in wheel arrangement, must run single ended, and is further handicapped with the addition of a tender to carry its fuel and water supply. The result has been much congestion at terminals; and the necessary roundhouses, always with the inevitable turn tables, ash pits, and coal and water facilities, have occupied much valuable land; and in addition steam operation has greatly depreciated the value of neighboring real estate. The contrast offered by the two large electric terminals in New York City is too apparent to need more than passing comment, and similar results may be expected on the fulfillment of plans for electrifying the Chicago terminals.

While it has been a simple matter to design electric locomotives to run double ended at the moderate speeds required in freight service, the problem of higher speed attainment, exceeding 60 miles per hour, has presented greater difficulties. The electric motor is however so adaptable to the needs of running gear design that electric locomotives are now in operation which can meet all the requirements of high-speed passenger train running. These results, also, are obtained with less than 40,000 lb. total weight, and 9,500 lb. non-spring borne or "dead" weight on each driving axle, and finally, but not least, with both front and rear trucks riding equally well, a success never before achieved in locomotives of such large capacity.

In connection with the riding qualities of electric locomotives, it is of interest to note the conclusions that the Committee of the American Railway Engineering Association, F. E. Turneaure, Chairman, reached in their report of 1917:

"From the results of the tests on the electrified section of the Chicago, Milwaukee & St. Paul Railway, the tests made in 1916 on the Norfolk and Western, and the few tests made in 1909 at Schenectady, N. Y., it would appear to be fairly well established that the impact effect from electric locomotives is very much less than from steam locomotives of the usual type. Comparing results obtained in these tests with the results from steam locomotives, it would appear that the impact from electric locomotives on structures exceeding, say, 25 ft. span length, is not more than one-third of the impact producted by steam locomotives."

There is as yet no general acceptance of a standard design of electric locomotive. Geared side-rod construction for heavy freight service and twin motors geared to a quill for passenger locomotives appear to find favor with the Westinghouse-Baldwin engineers, while the General Electric Company goes in for the simple arrangement of geared axle motors for freight and gearless motors for passenger locomotives. In both Switzerland and Italy the side-rod locomotive enjoys an almost exclusive field. How much of this preference for side-rod construction is due to the restrictions imposed by the use of alternating-current motors is hard to determine, but the facts available indicate both in this country and abroad the uniformly higher cost of repairs of this more complicated form of mechanical drive.

The electric railway situation in Italy is further complicated by the employment of three-phase induction motors with all the attendant handicaps of double overhead trolleys, low power-factor, constant speeds, and overheating of motors resulting from operation on ruling gradients with motors in cascade connection. In many respects the non-flexible three-

phase induction motor is poorly adapted to meet the varied requirements of universal electrification; and in consequence Italian engineers are still struggling with the vexing question of a system, which may, however, be in fair way of settlement through the adoption of a standard of 50 cycles as the frequency of a nation-wide interconnected power supply, thus throwing the preponderance of advantages to high-voltage direct current.

The extreme simplicity of the gearless motor locomotive appeals to many as does its enviable record of low maintenance cost, reliability, and high operating efficiency, as exemplified by its unvarying performance in the electrified zone of the New York Central for the past twelve years. Table XIII shows that the high cost of living did not appear to have reached this favored type of locomotive until the year 1918.

The records on the C., M. & St. P. locomotive are equally remarkable when considering their greater weight and more severe character of the service.

TABLE XIII—MAINTENANCE COSTS, NEW YORK CENTRAL.

	1913	1914	1915	1916	1917	1918
Number locomotives owned	48	62	63	63	73	73
Average weight, tons	118	118	118	118	118	118
Cost repairs per locomotive mile	4.32	4.03	4.45	3.78	4.01	6.26

TABLE XIV—LOCOMOTIVE MAINTENANCE COSTS, CHICAGO, MILWAUKEE & ST. PAUL RAILWAY.

	1916	1917	1918
Number locomotives owned	20	44	45
Average weight, tons	290	290	290
Cost repairs per loco. mile	8.21	9.62	10.87

In both these instances the cost of repairs approaches closely to three cents per 100 tons of locomotive weight. Giving due credit to the excellent repair shop service rendered in each case, it is instructive to note that three cents per 100 tons maintenance cost of these direct-current locomotives is less than half the figures given for any of the alternating-current locomotives operating in the United States or in Europe.

Compared with the cost of repairs for equivalent steam engines, the above figures for electric locomotives are so very favorable as to justify the general statement that electric motive power can be maintained for approximately one-third the cost of that of steam engines for the same train tonnage handled. As locomotive maintenance is a measure of reliability in service and in a way expresses the number of engine failures, it is quite in keeping with the records available to state also that the electric locomotive has introduced a new standard of reliability that effects material savings in engine and train crew expense as well.

While the first cost of electrification is admittedly high, it may in certain instances be the cheapest way to increase the tonnage carrying capacity of a single track especially in mountain districts where construction is most expensive and steam engine operation is most severely handicapped. In this connection a comparison of steam and electric operation on the C., M. & St. P. Ry. may be summarized as follows:

For the same freight tonnage handled over the Rocky Mountain Division, electric operation has effected a reduction of 22½ per cent in the number of trains, 24.5 per cent in the average time per train, and has improved the operating conditions so that nearly 30 per cent more tonnage can be handled by electric operation in about 80 per cent of the time it formerly took to handle the lesser tonnage by steam engines. This means a material increase in capacity of this single-track line which may be conservatively estimated in the order of at least 50 per cent and probably more. In other words, on this particular road, electrification has effected economies which sufficiently justify the capital expenditure incurred and furthermore has postponed for an indefinite period any necessity of constructing a second track through this difficult mountainous country.

A careful study of the seriously congested tracks of the Baltimore and Ohio Railroad between Grafton and Cumberland disclosed vitally interesting facts. Company coal movement in coal cars and engine tenders constituted over 11 per cent of the total ton-miles passing over the tracks. In other words, owing to the very broken profile of this division, the equivalent of one train in every nine is required to haul the coal burned on the engines. Taking advantage of this fact and the higher speed and hauling capacity of the electric locomotive and its freedom from delays due to taking on water and fuel, it is estimated that the three tracks now badly congested with present steam engine tonnage could carry 80 per cent more freight with electric locomotive operation. The coal output of the Fairmont District is largely restricted by the congestion of this division of the B. & O. R. R. and it is probable that equal relief with continued steam engine

A 5,000-TON FREIGHT TRAIN (100 CARS) ON THE CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY

operation could not be secured without the expenditure of a much larger sum for additional track facilities than would be needed to put electric locomotives upon the present tracks.

Further instances could be cited where the benfits of electrification are badly needed and many of these are coal carrying roads among which the Virginian Railway stands out conspicuously as a good opportunity to make both a necessary improvement and a sound investment.

Reviewing the progress made in a short twenty-year period, we have seen the steam turbine and electric generator drive the reciprocating engine from the stationary power field. The same replacement is now taking place on our ships, big and small, notwithstanding the fact that the marine reciprocating engine is a very good engine indeed and operates under the ideal conditions of steady load and constant speed. And now the steam locomotive must in turn give way to the electric motor for the same good reason that the reciprocating steam locomotive has become obsolete and fails to respond to our advancing needs. Electrification affords a cheaper and better means of securing increased track capacity and improved service than by laying more rails and continuing the operation of still more steam engines in the same old wasteful way.

To conclude the startling picture of our present railway inefficiency, we are today wasting enough fuel on our steam engines to pay interest charges on the cost of completely electrifying all the railways in the United States, fuel that Europe stands in sad need of and which England and Germany, the pre-war coal exporting countries, cannot now supply. With operating expenses mounting to 82 per cent of revenue, inadequate equipment and congestion of tracks, what we need in addition to constructive legislation and real co-operation on the part of the Government in the matter of rates and safeguarding invested capital, is wise direction in the expenditure of the large sums that must speedily be found and used to bring our railways abreast of the times. Accord full honor to the reciprocating steam engine for the great part it has played in the development of our railways and industries, but complete the work by replacing it with the electric motor and enter upon a new era of real railroading, not restricted steam engine railroading.

Measuring Thermal Expansions*

Accuracy of the Stretched Wire Dilatometer

By Arthur W. Gray

DETERMINATIONS of linear thermal expansivity involve:

(1) Production of temperature uniformity.

(2) Determination of temperature.

(3) Measurement of small length changes.

Of these, the last is by far the most difficult.

DIFFICULTIES IN MAKING RELIABLE MEASUREMENTS.

The difficulties that arise in connection with the measurement of length changes are of two kinds:

First, the displacements are generally so small that in order to attain even moderate percentage accuracy, high absolute accuracy is necessary. It is comparatively easy to arrange devices of sensitivity sufficient to indicate displacements smaller than one-tenth of a micron; but it is not quite so easy to attain such precision upon repeated attempts to measure the same length. It is not at all easy to make sure that such precision, when attained, represents real accuracy, that is to say, correctness.

In the second place, measurements of thermal expansions are far more difficult than ordinary length measurements requiring the same degree of accuracy. The very nature of the case demands that the body under investigation be measured at several different temperatures; and changes of temperature are always accompanied by displacements in various parts of the measuring apparatus. Unless special precautions are taken, these displacements give rise to errors which are always difficult, and often quite impossible, to determine with certainty. So-called compensating devices are generally unreliable. Rather than trust them when accuracy is of importance, it is better to design apparatus which will render the errors negligible, or at least will make them determinable with certainty.

It was for the reasons just given that the writer introduced the use of stretched wires in 1911 when designing for the Bureau of Standards the equipment still used in determining the thermal expansivity of materials in the form of bars.

STRETCHED WIRE METHOD FOR MEASURING LINEAR DISPLACEMENTS.

With the aid of such a simple device as a tightly stretched fine wire it is fairly easy to measure with great accuracy a displacement which occurs within a region otherwise difficult of access.[1]

Apparatus on this principle has been employed for the past eight years in the determination of thermal expansions. Two such arrangements of stretched wires are represented diagrammatically by Figs. 1 and 2. In each the expanding bar is indicated by AB. In Fig. 1, wires are freely suspended in contact with the ends of the bar and are stretched vertically by the weight of vanes immersed in oil, the viscosity of which is adjusted to damp any swinging of the wires so that their motions will be almost, but not quite, aperiodic. In Fig. 2, suitable for cases in which the bar is immersed in a liquid, wires are stretched upward to another bar CD rigidly connected with the central portion of AB. In both arrangements the transverse motions of the wires are observed through micrometer microscopes focused at convenient points E and F. Disturbances from changes in level are avoided by grinding ends of AB to form portions of a horizontal cylinder, the axis of which passes through the center of the bar.

ACCURACY AND RANGE OF THE METHOD.

Unless one has had actual experience with this method of rendering displacements accessible to measurement, it is difficult to believe the accuracy attainable when proper precautions are taken. Thousands of observations have convinced me that the method is the most reliable yet devised for the measurement of thermal expansions. I have used the arrangement of Fig. 2 in an oil bath maintained at any desired temperature from near —150 deg. C. up to +350 deg. C., and I have used the arrangement of Fig. 1 in an electric furnace at various temperatures up to about 650 deg. C. I have not personally tested the method at temperatures much above 650 deg. C. Sufficiently fine wires of nichrome or other non-oxidizable material strong enough at higher temperatures to sustain the weights of the damping vanes were not obtainable while I was at the Bureau of Standards. Nor were my ar-

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[1]Expansion measurements by this method were reported to the American Physical Society at the Washington meeting in December, 1911, and at various times since then. (A. W. Gray: "A New Type of Apparatus for Measuring Linear Expansion," *Phys. Rev.*, Vol. 34, p. 139, 1912.) The principle of the method was also described in a communication to the Washington Academy of Sciences. ("New Methods for Displacement Measurements and Temperature Uniformity Applied to the Determination of Linear Expansivity," *Journ.*, Wash. Acad. Sc., Vol. 2, p. 248, 1912.) See also "Production of Temperature Uniformity in an Electric Furnace," Bull. Bureau of Standards, Vol. 10, p. 451, 1914; Scientific Paper No. 219.

rangements completed for an atmosphere within the furnace which would permit the use of tungsten wires. Recently, however, Dr. Souder, who is now in charge of the Expansion Laboratory, informed me that the Bureau had obtained fine enough wires of a nickel-chromium alloy which, even in air, remained sufficiently strong at temperatures up to 1000 deg. C. Tungsten, if protected from oxidation, could probably be used up to 1400 deg. C., or perhaps even higher.[2]

The stretched wire method of measuring expansions has not yet been tried at temperatures below —150 deg. C., because suitable temperature baths have not been conveniently available. The pentane which was used for the bath liquid becomes so viscous when cooled to near —150 deg. C. that proper circulation is no longer possible. It would, however, be a simple matter to modify the apparatus so as to use a bath of liquid air; and, with such refrigerating facilities as are available in the Cryogenic Laboratory of Kamerlingh Onnes, the wire method could be used down to the very lowest temperatures producible with the aid of liquefied helium. It is merely a question of sufficient refrigeration and a suitable container for the bath.

The complete equipment which I planned for the Bureau of

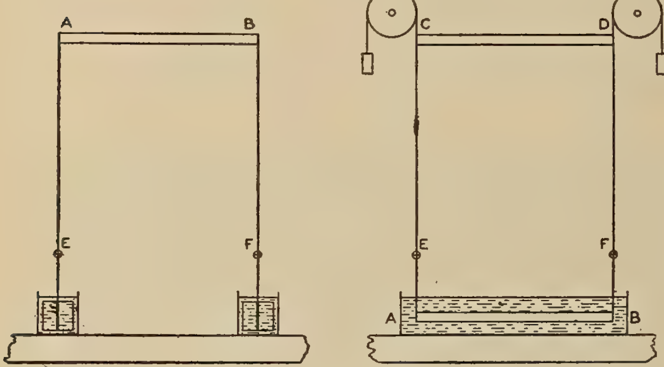


FIG. 1 & 2. DIAGRAM OF STRETCHED WIRE DILATOMETER

Standards has never been finished, and consequently has not been described; but some accounts of measurements made with this apparatus at various temperatures ranging from below —140 deg. C. to above 600 deg. C. have recently been published by my former assistants Schad and Hidnert, by Merica and Schad, and by Price and Davidson.[3]

The data contained in these papers, some of which are presented graphically, illustrate the performance of stretched wire expansion apparatus under conditions of ordinary routine tests. The precision is most clearly shown by Schad's and Hidnert's measurements of the expansivity of molybdenum. They found that all their length observations made at temperatures ranging from —142.5 deg. to +18.7 deg. C. were expressible by a quadratic equation with such precision that the probable error of a single observation was ±2.6 microns per meter. Likewise, the probable error of a single observation on heating from 18.7 to 305.3 deg. C. was found to be ±2.5 microns per meter. Since the specimen tested was only 20 cm. long, these values indicate that the probable error in making a single expansion measurement was about ±0.5 micron. Moreover, a second set of observations from room temperature to 304 deg. C., taken several days later, yielded an equation which agreed so closely with that obtained during the first test that the lengths determined from the two equations did not differ by more than 4 microns per meter, or 0.8 micron in length actually measured. Some of the slight differences observable between heating and cooling curves, and between curves obtained from different tests of the same specimen, are due to the fact that no solid has yet been found which assumes exactly the same dimensions every time it is

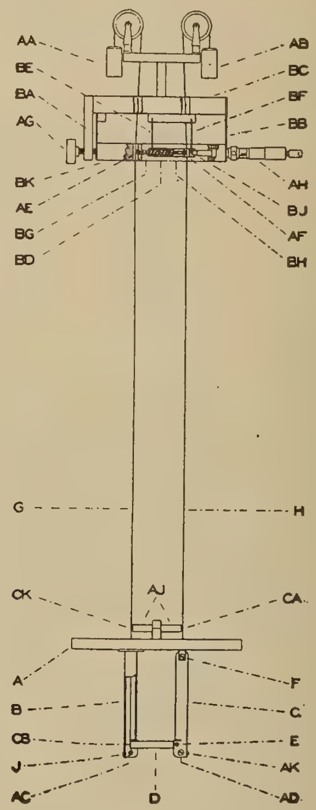


FIG. 3. SKETCH OF ESSENTIAL PARTS OF DILATOMETER

brought to the same temperature. Molybdenum repeats better than most substances, and is, therefore, well suited for expansion apparatus.

SIMPLE STRETCHED WIRE DILATOMETER.

While the equipment developed at the Bureau of Standards is very efficient for the accurate investigation of thermal expansivity over a wide temperature range, it is more elaborate than is necessary for most scientific or industrial purposes. A simple but reliable dilatometer which the writer made from material to be found in almost any physical laboratory may therefore be of sufficient interest to warrant a more detailed description that that already published.[4] The apparatus, which uses the stretched wire method of measuring linear displacements, could easily be adapted for commercial testing. It differs from the precision apparatus at the Bureau of Standards mainly in the substitution of an ordinary Brown & Sharpe micrometer screw for the expensive microscope comparator and reference bar. Fig. 3 is a somewhat diagrammatic vertical projection of the dilatometer partly in section.

[2]Jeffries recently found the equi-cohesive temperature of platinum to lie between 525 and 550 deg. C. This explains why I could not get platinum wire to sustain continuously the weights of even very light damping vanes when the temperature rose much above 600 deg. C. Jeffries found the equi-cohesive temperature of tungsten to be about 1350 deg. C. (Zay Jeffries: "The Amorphous Metal Hypothesis and Equi-Cohesive Temperatures," *Journ.*, Am. Inst. Metals, Vol. 11, pp. 300-323, 1917.)

[3]L. W. Schad and Peter Hidnert: "Preliminary Determination of the Thermal Expansion of Molybdenum," Bull. Bur. Standards, Vol. 15, pp. 31-40, 1919. P. D. Merica and L. W. Schad: "Thermal Expansion of Alpha and of Beta Brass between 0 and 600 deg. C., in Relation to the Mechanical Properties of Heterogeneous Brasses of the Muntz Metal Type," *Journ.*, Am. Inst. Metals, Vol. 11, pp. 396-407, 1917; Bull. Bur. Standards, Vol. 14, pp. 571-590, 1918. W. B. Price and Philip Davidson: "Physical Tests on Common High Brass Taken Parallel and at Right Angles to the Direction of Rolling-Appendix," *Trans. Am. Inst. Metals,* Vol. 10, 1916.

The expansion determinations reported by Price and Davidson were planned in detail by the present writer; the measurements and charts were made by Messrs. Schad and Hidnert; the specimens of brass were furnished by Mr. Price.

[4]Abstract of a paper presented at the Baltimore meeting of the American Physical Society. *Phys. Rev.*, Vol. 13, p. 142, 1919.

Minor constructional details are not represented in order that the essentials may stand out more clearly.

DETAILED DESCRIPTION OF SIMPLIFIED APPARATUS.

Extending vertically downward from the cover *A* of the temperature bath made of asbestos wood are two tubes *B* and *C*, the axes of which are separated by approximately the length of the specimen *D*. At the lower end of each tube are two pointed co-axial screws *E* for clamping *D* from opposite sides. One of the tubes, *B*, is rigidly attached to the cover *A*; the other, *C*, is hinged at *F* so as to permit free expansion of the specimen. Fine wires, *G* and *H*, of annealed tungsten, clamped to the lower ends of the tubes by means of the screws *J* and *AK*, extend vertically upward through the tubes and the cover for several decimeters above the latter, where they pass over pulleys and support weights *AA* and *AB*, which keep them tight and straight. The pins *AC* and *AD* cause the wires to bear firmly against the rounded ends of the specimen *D*. Small circumferential V-grooves in these pins center the wires and prevent them from slipping across the ends of the specimen.

At the upper end of the apparatus are two smooth round pins *AE* and *AF*, which bear against the wires *G* and *H*, a decimeter or so below the pulleys. By means of the screws *AG* and *AH* these pins move horizontally in the plane of the wires, so that the upper portions of these wires can be brought closer together or separated a measured distance.

Just above the cover of the temperature bath is placed a horizontal bar *AJ*, of low and known thermal expansivity, protected as far as possible from temperature changes accompanying warming and cooling of the bath below.

This bath, which is not shown in the illustrations, is of oil, heated electrically, and continuously stirred by a screw propeller, the containing tank being provided with suitable guides for insuring thorough mixing and circulation. If air is excluded to prevent flashing, "Renown" engine oil can be used to over 300 deg. C. Pentane gasoline remains sufficiently fluid down to about —150 deg. C. Although these two liquids will cover the entire range, kerosene is usually the most convenient substance when measurements do not have to be extended much beyond either 0 deg. or 75 deg.

After the specimen has been placed in the heating bath and temperature equilibrium has been reached, the upper end of each stretched wire is moved until the wire just touches the end of the bar *AJ*. Contact is indicated electrically by means of an inexpensive reflecting galvanometer in series with a dry cell and a suitable resistance. As the specimen *D* expands, it moves the wires away from the contact bar *AJ*. The magnitude of the expansion is determined from the movements of the screws *AG* and *AH* required to restore contact.

Only one graduated screw is actually used. The ordinary screw *AG*, of moderately fine pitch, moves a horizontal bar *BK*, to which are rigidly attached both the pin *AE*, which communicates the motion to the left-hand wire *G*, and the nut of the graduated screw *AH*, which moves the right-hand wire *H*. In this way a single micrometer screw is made to measure the total displacement of both wires. A Brown & Sharpe micrometer head is convenient for this purpose.

The movement of the bar *BK* is guided without lost motion by means of the thin flat strips of spring metal *BA* and *BB*, which suspend it from the bar *BC*. The smaller bar *BD*, which carries the pin *AF*, is likewise supported by the flexible strips *BE* and *BF* so that it is freely movable horizontally within a rectangular cavity cut through the central portion of *BK*. The spiral spring *BG* surrounding the rod *BH* presses *BD* firmly against the end of the measuring screw *AH*. The steel ball *BJ*, pressed tightly into the end of *BD*, makes an excellent bearing for the end of the screw.

The bar *AJ* is merely a piece of Pyrex glass tubing. (Fused quartz, because of its still smaller thermal expansivity, would be better.) Bearing firmly against each end of the tube, a tungsten wire (*CK* and *CA*) about 0.1 mm. in diameter is tightly stretched horizontally between two posts, one of which serves to connect the wire electrically with the galvanometer for detecting contact with the adjacent vertically stretched measuring wire. These posts, which may be ordinary machine screws with nuts, are not represented in Fig. 3. The ends of the tube are, of course, suitably ground so that the horizontal wires will be parallel to each other, and so that there will be no interference with the motions of the vertical wires. The horizontal wires define the effective length of the contact bar *AJ*.

PREPARATION OF SPECIMENS FOR TESTING.

The preparation of a specimen for an expansivity determination is an easy matter. All that is necessary is to cut off a rod of the required length and to round the ends smoothly, so that they form portions of a cylindrical surface. The rounding should, however, be accurately done, since its purpose is to prevent small angular displacements in the plane of the wires, causing errors by changing the distance between contacts. The easiest and best way of producing the cylindrical surfaces is by grinding.

A simple tool is used for holding a specimen during this operation. By means of radial screws near each end the rod is firmly clamped within a metal tube. Midway between its ends this tube is pivoted between two co-axial pointed screws which hold it within the arms of a forked bar of rectangular cross-section. As the bar is gradually advanced toward the edge of the grinding wheel, the tube containing the specimen is rotated between the pivot screws of the fork.

A screw-operated slide-rest is not at all necessary for feeding the specimen toward the grinding wheel. With the exercise of a little care the movement can be sufficiently well guided by pressing one corner of the forked bar into the dihedral angle of a support formed by fastening a straight strip of wood or metal upon a flat surface. The bar is advanced toward the wheel by gentle tapping against the farther end. Even glass can be ground in this way without difficulty.

Near each end of the tube which holds the specimen during grinding are two small holes, one from each side. These form convenient guides for drilling the little conical depressions or holes (*CB*, Fig. 3) that receive the pointed ends of the clamping screws *E*.

SOURCES OF ERROR.

The accuracy of the simple dilatometer described above is limited mainly by the accuracy with which contact can be detected between the stretched wires and the bar *AJ* above the temperature bath. Immediately before taking a series of readings the contact surfaces of both the wires and the bar should be washed with a little ether applied by means of a camel's hair brush. With delicate touch the left-hand screw *AG* is then cautiously and steadily turned until the galvanometer gives the first slight indication of contact between the wire *G* and the end of the contact bar *AJ*. A small deflection that increases with continued advance of the screw indicates a better contact than a sudden, large deflection. After contact has been established with the left-hand wire, the measuring screw *AH* is advanced until the right-hand wire *H* makes contact with *AJ*. At each temperature or measurement, settings of both screws should be repeated a sufficient number of times to make sure that good contacts are being obtained. Failure to obtain a series of concordant readings is evidence that something is wrong—probably a dirty contact or lack of care in turning one of the screws.

The effect of errors in the measuring screw varies inversely as the ratio of the distances from the contact bar *AJ* to the pins *AE* and *AF* for moving the wires and to the specimen *D*. In the apparatus actually used these pins were 600 mm. above and the specimen 150 mm. below the bar, so that the micrometer screw *AH* measured four times the expansion of the specimen. The results showed that with proper use deviations of individual screw readings from the average should not

exceed 5 microns. The average deviation of 107 individual readings from the average reading for each temperature was less than 2 microns, corresponding to an average deviation of 0.5 micron in determining the expansion of the speciment.

Corrections must be applied on account of length changes in *AJ* and in *BK* brought about by temperature changes occurring in these bars during the course of an expansivity determination. With a dilatometer in which the wires multiply the elongations by 4, the apparent expansion of the specimen must be corrected as the expansion of *AJ* and ¼ the expansion of *BK*. Although it is easy to calculate these corrections if the expansivities and the temperatures of *AJ* and *BK* are known, it is more convenient to render the corrections negligible, or at last very small, both by using materials of low expansivity for these parts of the apparatus and by protecting them from temperature changes—especially changes caused by convection, conduction and radiation from the bath for heating the specimen under test.

CONCRETE ILLUSTRATION OF AN EXPANSIVE DETERMINATION.

A concrete example illustrating the capabilities of the above-described simple apparatus is afforded by a determination of the thermal expansivity of some optical glass.[5]

A summary of the measurements made is contained in the

THERMAL EXPANSION OF OPTICAL GLASS

A	B	C	D	E
23.45	0.0	±0.5	—2.8	7
77.51	25.5	0.6	—2.5	3
78.21	29.2	0.4	—1.0	8
127.24	47.2	0.4	+0.2	9
170.55	67.2	0.2	+2.0	6
227.83	95.8	0.3	+3.0	10
254.13	110.0	0.6	+3.2	9
265.75	115.5	0.5	+3.0	7
276 62	120.8	0.5	+3.0	9
286.39	124.2	0.4	+4.0	9
297.07	130.0	0.6	+4.5	6
307.81	133.5	0.4	+5.8	7
30.85	13.8	0.6	—2.0	7
29.96	13.0	0.5	—1.2	10

A. Temperature Centigrade.
B. Expansion in microns of 6 cm. specimen.
C. Average deviation in microns from average.
D. Correction in microns for temperature changes in apparatus.
E. Number of micrometer screw settings averaged.

accompanying table. In this table Column A gives in degrees Centigrade the temperatures of the oil bath in which the specimen was heated. These temperatures were determined by platinum resistance thermometer; a mercurial thermometer was used as a rough indicator. Column B gives in microns the expansion of the specimen observed on heating it from 23.45 deg. to each temperature recorded in Column A. In obtaining these values the corrections given in Column D were added to the apparent expansions indicated by the measuring screw. For calculating the corrections the linear expansivities of the brass bar *BK* and of the Pyrex glass tube *AJ* were assumed to be 0.000018 and 0.0000032 per degree Centigrade, respectively. The magnitudes of these corrections could have been greatly reduced by proper choice of materials together with proper thermal insulation.

The precision attained in measuring the expansions is indicated by Column C, which gives opposite each temperature the average deviation in microns of the individual indications of the measuring screw from the average value observed at that temperature. The deviations here recorded, which correspond to elongation of the specimen under measurement, were obtained by dividing the corresponding deviations of the actual screw readings by 4, since the stretched wires multiplied the specimen elongations by 4. Column E shows the number of micrometer screw observations that were averaged at each temperature to obtain the values under B and C. Examination of the table shows that, for the 107 contact observations represented, the average deviation was only about 0.46 micron. This gives some idea of the high precision attainable with a stretched wire dilatometer even when the construction of the instrument is crude.

A plot representing the observations recorded in the table is shown in Fig. 4. The straight line corresponds to an expansivity of 0.00000794 per degree Centigrade. The last two observations, which were made the day following the observation near 308 deg., are represented by the open circles. Such failure of a glass to return to its original length upon cooling after strong heating is frequently observed.

Although Fig. 4 indicates an accuracy sufficient for most scientific or industrial purposes, it should be borne in mind that the specimen tested was only 60 mm. long and that the corrections given in Column D of the table are both considerably larger and considerably more uncertain than need be. If the errors involved in the corrections be rendered negligible by the means indicated above, the relative accuracy of the expansion measurements will be increased in the same ratio as the length of the specimen under test is increased, since the deviations in Column C represent absolute, not relative, precision in length measurement.

VARIATIONS OF THE STRETCHED WIRE DILATOMETER.

The apparatus actually constructed as outlined above illustrates merely one particular arrangement for applying the general principles of the stretched wire method. It was hastily

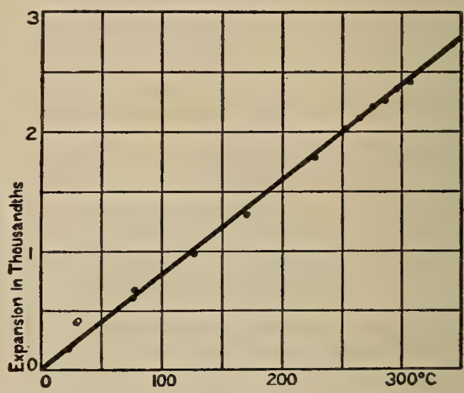


FIG. 4. THERMAL EXPANSION OF OPTICAL GLASS

designed and built to meet an emergency. Various details could obviously be modified. For example, two independent graduated screws for moving the stretched wires *G* and *H* would be a convenience; any sensitive detector of contact is usable; tungsten wires are not necessary, etc. Moreover, micrometer screws can be arranged to replace microscopes for use with either an air bath (as in an electric furnace) or a liquid bath; so that the range of application even in the simplified form of dilatometer is not limited to the interval between room temperature and 300 deg. C.

Nor is the application of the stretched wire method limited to the case of thermal expansion. The writer has already used wires for measuring magnetostriction in nickel steels at temperatures ranging from —75 deg. to +300 deg. C. Wires could easily be adapted to the construction of an extensometer for measuring deformations of materials during any kind of testing, especially when it was desired to control the temperature of the test piece. In fact, there appears to be no other method that is quite so reliable for accurately following linear displacements that occur in regions which are difficult of access.

[5]At the request of Dr. Arthur L. Day, Optical Glass Committee, War Industries Board, the writer undertook to determine the expansivity of this glass, which had been produced under the direction of the former for naval searchlight mirrors. The dilatometer shown in Fig. 3 was hastily designed and constructed especially for this work.

CORRECTION.

WE regret to state that in the article on "Non-Rolling Passenger Liners," p. 232 of the March issue of the SCIENTIFIC AMERICAN MONTHLY, the author's name was given as "Edward A. Sperry." It should have been "Elmer A. Sperry." The story of Mr. Sperry's achievements as an inventor is told in the SCIENTIFIC AMERICAN of April 17, 1920.

Science and National Progress

Edited by a Committee of the National Research Council

Dr. Vernon Kellogg, Chairman, Dr. R. M. Yerkes, H. E. Howe

The National Research Council is a co-operative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

BLUE EYES AND BLUE FEATHERS.

By Wilder D. Bancroft.

Professor of Physical Chemistry, Cornell University and Chairman of the Division of Chemistry and Chemical Technology, National Research Council.

The color of red paint or of yellow paint is due to red or yellow pigments, which owe their color to their chemical nature. These are called pigment colors. There are other colors which are due to the physical structure, and which are therefore called structural colors. The rainbow, for instance, is not a painted band in the sky. In fact, no two people see the same rainbow. Structural colors may be due to a number of causes and to understand them it is necessary to start almost at the beginning. An absolutely smooth, reflecting surface is invisible. We realize this very often when we come unexpectedly face to face with an exceptionally good mirror. It was suggested by a German that the Zeppelins should be coated with a polished metallic surface which would make them perfectly invisible. While it would be impossible to see such a surface, there is some doubt whether this would be a great success from a military point of view, because almost anybody would realize that something queer was going on if he were to see a reflected section of the earth's surface apparently moving along up in the sky.

If we put powdered glass in a liquid having the same index of refraction as the glass, no light is refracted when passing through the mixture and consequently the glass is invisible. If a glass rod be dipped into such a liquid, the rod seems to melt and disappear when it touches the surface of the liquid. Since different colors may have different indices of refraction, it happens sometimes that the glass will be invisible for certain rays, which are transmitted without change, while other rays are scattered by the glass. Under these circumstances the mixture of glass and liquid may transmit only yellow light and will appear yellow. At some other temperature it may transmit only red or only blue. This is known as the Christiansen effect, from the man who first studied it.

If we have a thin film with light reflected from the front and the back surfaces, it may happen that the crest of certain waves reflected from one surface will coincide with the hollow of waves reflected from the other surface, in which case this particular color will disappear and the place where this disappearance occurs will appear to have the complementary color. The colors of thin films are often known as Newton's Rings. We are quite familiar with them in the case of soap bubbles and with oil films on the ground. In the streets of Washington the colors due to oil films are exceptionally brilliant; but this is not due to any particular brand of oil which is spilled there. It is because the streets are asphalted and consequently there is practically no reflection of light from the asphalt surface to interfere with the colors of thin films. This is a very good illustration of the importance of a dark background in the case of structural colors.

We may get colors by reflection and refraction. The rainbow is an illustration of this. The old-fashioned cut-glass chandelier gives a good example of the colors that may be produced by light passing through a prism. If we have a number of lines ruled parallel and very close together on a smooth surface, this gives us what is known as a diffraction grating, which may spread a ray of light out in a way very similar to a prism. Agates are composed of thin films about 0.001 of a millimeter in thickness, and when the agate is properly cut it may behave like a diffraction grating. In the case of mother-of-pearl, we have alternate layers of calcium carbonate and an organic material. These layers overlap very slightly in a regular fashion and consequently act to some extent like a diffraction grating, giving rise to the peculiar effect known as pearly lustre.

The reflection of light by powdered material may produce a number of interesting color phenomena. When white light is scattered from a surface instead of being reflected as in a mirror, it gives rise to the sensation of white. A block of ice is not white, because it does not scatter the light. If the ice is powdered, or still better if we have snow, the light is scattered and we call the snow white. Instead of having solid particles of ice in air we may have air bubbles embedded in liquid, in which case we get a white froth or foam. If the blue crystals of copper sulphate are ground to a fine powder, the light passes through such fine layers of the material that it does not become colored blue to any appreciable extent. On the other hand, the light is scattered from the powdered surfaces, and the powdered copper sulphate looks white instead of blue. When silver is precipitated by an electric current, it does not come down with a mirror-like surface, but rather in a mass of tiny crystals which scatter the light in every direction. Consequently electrolytic silver is white and only has the characteristic appearance of silver after it has been burnished. There is no white pigment in any white flower or in white hair, and probably not in white bark. The white color of the lily is due to the presence of innumerable air bubbles and the same is true of white hair. In order that hair may turn white in a single night, it is not necessary for the original pigment to disappear and for white pigment to develop. It is only necessary for a mass of minute air bubbles to be formed in the hair as a result of worry. While this accounts for the physical change, we are as much at a loss as ever to know why intense grief should develop air bubbles in the hair.

The scattering of light by a powder or by the fibers of a sheet of paper is due to the difference in the index of defraction between the solid particles and the air. If we replace the air by some liquid having very nearly the same index of refraction as the solid particles, these latter will cease to be white and will become more transparent. It is well known that oiled paper is distinctly translucent. If powdered copper sulphate were immersed in a liquid having about the same index of refraction as the crystals, these would probably become blue. This experiment has not been tried; but there is a more interesting one which has puzzled people for a good while. In the zoölogical gardens some flamingoes are much redder than others. At one time it was thought that the redness was connected with a fish diet; but flamingoes have been raised which had bright red feathers even though the birds had never eaten fish, so this explanation had to be given up. It is now believed that the brilliancy of the color is due to the presence of oil in the feathers, this making them more translu-

cent and bringing out the red color. Water colors always become paler as the water dries out, because the pigment is then surrounded by air and not by water. Some people have gone so far as to say that white pigments do not occur in nature in living beings; but this is an over-statement. Some butterflies have a whitish pigment in their wings and the white bellies of many fishes are due to the presence of a substance called guanin, and not to air bubbles.

Complete absorption of light gives the sensation known as black. Pulverulent silver is black because the crystals are so arranged that all the light is absorbed by reflection forward and back. This can be shown in another way. If we take a bunch of steel needles and place them with their points side by side facing the observer, the mass will appear black, although we know that no single needle is black in itself. The rich color of velvet is due to its trapping the light, and the peculiar effect known as damask is due to the fibers being arranged in two different ways, so that one set absorbs more light than the other. Trees and grass may act as light traps when seen from above and they are said to look black to aviators. If we have a material which absorbs light so completely that the powder is black, we shall get all gradations between the original color and black if we grind up such a substance, just as we got all variations between blue and white by grinding crystals of copper sulphate. If we start with yellow gold and make it more porous, it will become brown before becoming black. This happens unintentionally in the assaying of gold, a brown powder being obtained which people have thought was an allotropic form of the metal. It is merely a porous gold and when it is heated until the crystals sinter together and become less porous, the yellow color of gold reappears.

When powders are grouped, there may also be a change of tint owing to the fact that the pigment or absorption color varies with the thickness of the film. This will show up just as well with thin layers as with powders. Both cobalt glass and cyanine are blue in thin layers and red in thick ones. Large crystals of potassium ferricyanide are red and the color changes to yellow when the crystals are ground to powder. It has been made probable by the Geophysical Laboratory that rouge would be yellow if we could grind it fine enough. So far this has not yet been done; but it is merely a question of time when somebody will make yellow rouge, in spite of the contradiction in terms which is implied. In all these cases adding a liquid having approximately the same index of refraction as the powders would change the color towards that of the larger crystals.

If we have very fine particles suspended in a transparent solid, liquid, or gas, these particles scatter blue light much more than they do red light, and consequently such a mass appears red by transmitted light and blue by reflected light. Skimmed milk is an instance of this sort, being distinctly bluish by reflected light and reddish by transmitted light. Tobacco smoke is also blue by reflected light and red by transmitted light. The blue color of the sky is due to light which is scattered by drops of liquid or by particles of dust in the air. The intensity of the color is undoubtedly increased by the fact that we see this against the black background of infinite space, so that the color is not changed by light reflected from the boundaries of the atmosphere.

There is no blue pigment in blue eyes and it was pointed out by Tyndall years ago that the blue of the eye is really the blue of turbid media, and is thus analogous to the blue of the sky or the blue of skimmed milk. At the back of the iris there is a dark pigment known as the *uvea*, which prevents the reflection of light and keeps the color of the blood behind it from being seen. When this dark pigment is absent, we have an albino and a pink eye. The various stages between the blue and the gray eye are due to differences in the coarseness of the particles giving rise to the blue color, the blue color being the more intense the finer the particles. This is probably the reason why babies' eyes are so very blue, because the suspended particles tend to grow coarser with increasing age. All other people have a yellowish-brown pigment in the front of the iris, and the combination of the structural blue with the yellowish-brown pigment gives rise to the green, hazel, brown and black eyes. Except with people who have very black eyes, the pigment in the front of the iris does not develop at birth, just as the teeth do not come till later. Consequently most babies have blue eyes, the color changing to hazel, brown or black as they grow older, while the reverse change never occurs. Once in a while we see a man whose eyes are colored differently. This means that pigment has developed in one eye and not in the other, or that the pigment has developed unequally in the two eyes. The green eye is due to the combination of structural blue with the pigment yellow. While this is not a common type in human beings, we get it very markedly in the case of the green tree-frog, which has no green pigment and whose green color is due to structural blue with a yellow pigment overlaying it. If we scrape the pigment layer off the back of an unfortunate frog, he turns blue. The Latin name of the Australian tree-frog means "the sky-blue frog," because he is blue when he comes to us preserved in alcohol, the alcohol having dissolved the yellow pigment.

If we leave out of account feathers with a blue metallic lustre, which may constitute a special case, we may say that there is no blue pigment in the feathers of any bird. This means that the blue of the kingfisher, the indigo bunting, the blue-jay, and the blue-bird, is not due to blue pigment, but is a structural color. The only pigment in the blue feathers of these birds is a dark brown one which apparently serves merely as a background, just as in the case of the blue eyes. The best explanation of the blue feather is that the horny matter is filled with an enormous number of minute air bubbles, which scatter blue light and transmit red, which is absorbed by the dark background. The blue feather is therefore the same in principle as, and the opposite in detail from, the blue sky. The color of the sky is due to the scattering of light by particles of liquid or solid suspended in a gas, the air. The blue of the feathers is due to the scattering of light by bubbles of gas, air, suspended in a solid medium. While this explanation is undoubtedly the right one, nothing analogous to a blue feather has yet been made in the laboratory. This is one of the things that people must do in the future.

In this country the tufted titmouse is a gray bird with no brilliant colors; but the German titmice show great differences in color. One variety is green on the back, due to structural blue overlaid by a pigment yellow, and yellow on the belly. In another variety the brown pigment which is essential to the structural blue has not developed and the bird is consequently yellow all over. There is a third form in which the yellow pigment has not developed and the bird is therefore blue on the back and white underneath. One would like to think that the differences in color between the male and the female redstart were of this type and were due to the presence in the male of a single color which is lacking in the female; but this seems not to be the case.

The gorgeous sunset colors are due to the red light which is transmitted through the cloudy sky and is the reverse of the blue of the sky. Water is apparently blue in itself when one looks through a sufficiently long layer. If, however, there were nothing to reflect the light back, the water would, of course, look black, and certain lakes do show exactly this phenomenon. If there is a small amount of reflecting particles, the water looks blue. With more suspended particles a certain amount of yellow is sent back, and the water becomes green. In the tropics the water is an intense blue, except near the shore, where it becomes an almost equally intense green. The water of the Rhone where it flows out of the Lake of Geneva is blue, while the Rhine at Strassburg is green, and we find that the Rhine contains seventy per cent more suspended calcium carbonate than the Rhone. Sometimes the water in a swimming tank will be as green as crême de menthe. This is due to suspended solids in the water. The same effect can oc-

casionally be obtained in a porcelain-lined bath tub. The clear brown brooks that one finds in many places in New England owe their color to the presence of a brown material of the nature of tannin, so this would really be a pigment color and not a structural one.

If a substance absorbs light very strongly, it may also reflect that light selectively, in which case the substance has what we call a surface color, due to resonance. Instances of this sort are very common among the so-called aniline dyes. For instance, crystals of magenta transmit red but reflect green Substances having marked surface colors show some very extraordinary properties when present in the form of very finely divided particles. Indigo in mass transmits blue and reflects red. If we make a colloidal solution of indigo with very fine particles, we find that it transmits red and scatters blue light. Without going into the theory of this, we may make the assumption that a substance which has a surface color will transmit, in finely divided form, the light which it ordinarily reflects, and will scatter the light which it ordinarily transmits. This tentative hypothesis works out very well as a means of explaining the colors of colloidal gold and colloidal silver. The apparent surface color of gold is yellow; but if we make the light pass a number of times between two surfaces of gold, we find that the resulting color is red and not yellow. A thin film of gold transmits green. In accordance with the hypothesis, we find that a colloidal solution of gold having very fine particles transmits red light and scatters green light. If the particles are coarse enough so that the peculiar phenomenon of resonance does not take place, the particles scatter yellow or brown light and transmit blue. As we see it ordinarily, silver has no especial color; but after multiple reflection, we find that the surface color or silver is yellow. A thin film of silver transmits blue and a colloidal solution of silver consequently transmits yellow light and scatters blue. With coarser particles, we get the transmission of blue, which is in line with the behavior of silver films, and the silver scatters the complementary color, which is blue. Sodium fogs scatter violet light, for which the vapors are transparent.

Michelson, of Chicago, has shown that the brilliant colors of butterflies are due in many cases to surface colors so that it is probable that the wings of the butterflies are colored by solid pigments, which behave like such aniline colors as magenta.

We are accustomed to say that metals have a metallic lustre and that glass has a vitreous lustre; but this does not seem to get us ahead at all. If one asks a physicist what constitutes metallic lustre, he is very likely to say that metals conduct electricity and that the electrons which are present give rise to the sensation of lustre. This cannot be the whole truth, because an empty glass test-tube placed in water and looked at so as to give total reflection, is more metallic than mercury itself. Also, if we take a black image on a white ground and a white image on a black ground and combine these two in a stereoscope, we do not get a sensation of gray—we get metallic lustre. A similar effect is obtained if we have a yellow image on a blue ground and combine it with a blue image on a yellow ground. This shows that the problem of metallic lustre is a psychological one in some cases and possibly in all. It seems probable that one gets the sensation of metallic lustre whenever we have a nervous flutter or unsteadiness of attention, as when one combines two pictures having different degrees of brightness. The elements of fatigue would enter in very largely here and some people are much more sensitive to binocular lustre, as it is called, than others. Woolen goods striped black and white appear lustrous to a few people, though not to most. This seems to be an exaggerated case of the eyes wandering over the surface in a jerky manner.

With metals there is reflection from the surface and from a plane only just below the surface, this giving rise to the flutter effect. When looking at a thing which is not in itself a metal, the sensation of metallic lustre will be attained more easily if the texture of the surface of the material resembles that of a metal. We also get the sensation of lustre in cases in which there is simultaneously a roughened surface and a high reflection of light. The most familiar instance of this is the silvery streak which marks the reflection of the moon from a water surface rippled by the evening breeze. The wavelets make the surface of the water seem rough and the accompanying high reflection of light makes the water look metallic, even more metallic than the disk of the moon itself.

Even in the best colored moving-picture films, we do not get the sensation of metallic lustre because both eyes are looking at the same image. It seems probable that this could be overcome in case the photographs were taken by means of two or more lenses sufficiently far apart. On the other hand, it would be very easy to overdo this, with the result either of getting a blurred image or of getting one with a metallic shine over everything, which would be worse than the present arrangement.

What is probably the color of colloidal particles is to be noticed with gems. Colorless topaz is made orange by radium and heating makes it colorless again. Ultra-violet light tends to change the orange, due to the radium, to a lilac. Blue sapphires are changed to yellow by radium, and yellow sapphires are changed to blue by ultra-violet light. Sapphires become colorless when heated and white sapphires are turned yellow by radium. In other words, in a good many cases, gems become colorless when heated, and the effects of radium and of ultra-violet are antagonistic. There is no known substance which behaves like this when present in mass. Consequently one is forced to the conclusion either that many of the gems are colored by hitherto unknown elements, or that the color is due to colloidal material which behaves differently from the same substance in mass. The second explanation is the more probable one, because we know that ruby glass, which is colored red by colloidal gold, becomes colorless if heated too hot, and the red color changes to blue if the glass is heated moderately for a long time. So far, however, no one has duplicated in the laboratory the color phenomenon shown by the gems and we consequently do not know what the real coloring matter is in many cases.

MEAT AND MILK IN THE FOOD SUPPLY

(Report of the Committee on Food and Nutrition of the National Research Council, April 3, 1920)

It has long been known, but perhaps never sufficiently emphasized, that the milk cow returns in the human food which she yields, a very much larger share of the protein and energy of the feed she consumes than does the beef animal. Dr. Armsby, probably the leading expert of this country on animal nutrition, has estimated (Science, August 17, 1917) that of the energy of grain used in feeding the animal there is recovered for human consumption about 18 per cent in milk, and only about 3½ per cent in beef.

In an official Report on the Food Supply of the United Kingdom, it is estimated that to produce 100 calories of human food in the form of milk from a good cow, requires animal feed of 2.9 pounds starch equivalent; 100 calories milk from a poor cow is estimated to require the consumption of 4.7 pounds; while to produce 100 calories of beef from a steer 2½ years old it is estimated that 9 pounds of starch equivalent in feed are required.

Stated in terms comparable with those used by Dr. Armsby, this would mean that the good milk cow returns 20 per cent of the energy value of what she consumes, the poor milk cow 12 per cent, and the good beef steer only 6 per cent. Although this estimate is more favorable to the beef steer than is that of Dr. Armsby, yet even in this estimate it will be seen that the poor cow is twice as efficient, and the good milk cow more than three times as efficient as the beef steer in the conservation of energy in the food supply.

Considering the whole length of life of the animal, Professor Wood, the leading English agricultural expert, estimates that the cow returns in milk, veal and beef, 1/12 as much food as she has consumed, while the beef steer returns only 1/64. In other words, the cow is five times as efficient as the beef steer as a food producer when the whole life cycle of the animal is considered. Similarly it has been estimated by Cooper and Spillman (Farmers' Bulletin, No. 817, 1917, U. S. Department of Agriculture) that the crops grown on a given area may be expected to yield from four to five times as much protein and energy for human consumption when fed to dairy cows as when used for beef production. As Wood has very strikingly shown, the longer the time that the beef animals are fattened on grain, the less economical the process becomes.

Quite recently Dr. Armsby has pointed out (Yale Review, January, 1920) that "the dairy cow shows the highest efficiency of any domestic animal, both as regards conversion of food and availabality of the product for man."

Not only is the milk cow several times more efficient than the beef steer in the conservation of proteins, fats, and carbohydrate for human consumption, but in the gathering and preparation of mineral elements and vitamines she contrasts even more favorably with the beef animal. It is largely because of its richness in calcium and in fat-soluble vitamine that milk is the most efficient nutritional supplement to bread or other grain products.

Meat is strikingly poor in calcium and does relatively little to balance a diet consisting largely of bread or of other products of seeds. It does, of course, supplement the protein, but American dietaries would nearly always be adequate as regards protein even without the meat that they contain. On the other hand, dietaries containing little or no milk are very apt to be inadequate as regards calcium. Detailed analysis of the results of hundreds of American dietary studies shows that in practice the adequacy of the calcium intake depends more largely on the sufficiency of milk supply than upon any other factor, or, in fact, than upon all other factors combined.

The vitamines furnished by hay and grains, and thus consumed by cattle, are stored in the animals' tissues to only a limited extent, but they are transferred in relative abundance to the milk. Hence the vitamines of the coarse material of grain, not directly available as human food, are brought into form for man's use very efficiently through milk production, and very inefficiently through the production of meat.

Thus the result of recent studies in nutrition, which have made clearer the importance of the mineral elements, and vitamines, is to emphasize strongly the great desirability of a more abundant milk supply, even if this should somewhat reduce the production and consumption of meat. Our present knowledge of nutrition justifies more fully than ever before the statement that "the dietary should be built around bread and milk," bread or other grain products being the foods which furnish the most nutriment for their cost (whether in money or in land and labor) and milk being by far the most efficient nutritional supplement to bread or other grain products. Therefore somewhat more of our grain crops than is the case at present should come directly into human consumption to augment the bread supply, and of the grain fed to cattle more should be used for the production of milk, and less for the production of meat.

In general, 10 pounds of grain may be expected to produce not over one pound of meat or about three quarts of milk. If the three quarts of milk cost the consumer more (because of greater labor cost in production) they are also certainly worth more to him. In so far as things as different in their nutritional properties as meat and milk can be compared, it is fair to say that one quart of milk is at least as great an asset in the family dietary as is one pound of meat. The per capita consumption of meat in the United States is so high that it might be reduced by one-third or even one-half with little or no nutritional loss, while a corresponding increase in milk consumption would certainly constitute a great improvement in the average American dietary. We are confident that a moderate shifting of emphasis from meat to milk will help in the normal evolution of American agriculture and improve the food economy and public health of the American people.

THE PROPER TIME OF DAY TO GATHER FRUIT.

The Bureau of Plant Industry of the United States Department of Agriculture has recently published some important information with respect to the hour at which fruit should be gathered, which is by no means a matter of indifference as might be thought. On the contrary its shipping quality has been found to depend upon its temperature when plucked, and this naturally depends upon the time of day. Botanists have long ago known that certain portions of plants are capable of attaining a temperature considerably above that of the surrounding air. During the middle of the day direct sunshine frequently causes a very marked and rapid rise of temperature in small fruits. This fact was noted by Messrs. Stevens, Neil and Wilcox with respect to huckleberries in 1916, and inspired fresh researches especially in 1918, with respect to other fruit.

The method of investigation was as follows: Specimens of the fruit mentioned were gathered hourly between the hours of 6 A. M. and 7 P. M. on sunny days and placed in baskets, each containing about one liter. After each collection of fruit a thermometer was placed in the middle of the basket among the mass of fruit and the temperature noted while at the same time the external temperature was registered by a control thermometer. The absolute figures are of but small importance but interesting deductions may be derived from the differences noted at the same hour between the figures recorded by the two thermometers. The extreme difference noted varied in amount and in the time when recorded according to the kind of fruit. But the maximum difference was always registered betwen 10 A. M. and noon.

In the case of strawberries it was 9.5° C. at 12 M.; for a variety of currants it was 9.0° C. at 12 M.; for another variety of currants, 6.5° C. at 10 A. M.; for the gooseberry it was 4.5° C. at 10 A. M.

The minimum difference of temperature, on the contrary, always occurred in the morning and evening, and was almost nil during the night. An effort was also made by inserting the bulb of the thermometer into the pulp of the fruit to discover whether there was an appreciable difference in temperature between the center of the fruit and its outside, but this difference was usually found to be extremely slight. These experiments have as their object the determination of the reason why lots of fruit gathered in the same gardens at the same season, only a few hours apart and in practically the same conditions of weather, sometimes arrive at market in a very different condition, although packed and shipped as soon as gathered in all cases, and after the same number of hours of travel.

Records kept for fifteen years with respect to peaches (a very fragile fruit) have shown that peaches gathered in the middle of the day usually bear shipping badly and we are forced to the conclusion that the keeping qualities of small fruits depend upon their temperature when gathered.

Consequently, horticulturists are advised to avoid the hot hours in the middle of the day for gathering fruit, particularly upon sunny days. In cloudy weather the hour of gathering is of less importance. The early hours of the morning, after the comparative coolness of the night are best of all. Contrary to what one might think it is far better, in case the train upon which the fruit is to be shipped does not reach the nearest station until midday, to gather the fruit early and keep it properly wrapped in baskets in the shade, rather than to leave it upon the trees until 10 or 11 o'clock with the idea of shipping it that much fresher.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

THE IMPORTANCE OF SPARK PLUGS.

THE importance of the ignition system in the operation of internal combustion engines is known to all users of automobiles, but only recently has such apparatus been subjected to scientific investigation.

During the war, it was discovered that the faulty operation of airplane engines appeared to be due very often to the improper functioning of the ignition system and particularly the spark plugs.

The importance of the problem was such that the Bureau of Standards was asked by the National Advisory Committee for Aeronautics, in November, 1916, to undertake a study of the causes of failure of spark plugs, and to develop, if possible, a superior type of plug. It was apparent that a great deal of the trouble in spark plug operation was due to the use of an imperfect insulator and the Bureau's efforts were, therefore, largely directed towards the perfecting of a more satisfactory form of spark plug porcelain. The program which was finally adopted consisted in the making of a large number of samples of insulators by the Ceramic Laboratory of the Bureau which were then tested for their electrical properties by the Electrical Division of the Bureau.

As a result of this work, an insulator was produced which proved in laboratory and service tests to be superior to any heretofore used. The formula for its composition was given to the manufacturers and spark plugs using it are now being produced commercially.

The methods of testing spark plugs are based on service requirements. To be perfectly satisfactory, a spark plug ought to be able to cause a spark to pass between its points under the worst conditions existing in the engine cylinder. This requires that the insulation between the central electrode and the outer shell of the plug shall maintain its non-conducting properties throughout a wide range of temperatures and when covered with oil or carbon. The voltage across the gap must be high enough to cause the passage of a spark through the highly compressed gas in the cylinder and sometimes even when a drop of oil adheres to the sparking points; likewise the plug must be gas-tight.

It is perhaps not generally known that while the actual leakage of gas through a faulty plug is not large enough to appreciably affect the power developed by the cylinder, it does cause rapid deterioration of the plug itself, due to the overheating and subsequent breakdown of the insulator. Absolute gas-tightness is, therefore, one of the essential requirements of a satisfactory plug. Besides the requirements above outlined, a plug should be easy to clean and this requires that it be simple in construction and readily taken apart.

Many commercial spark plugs which possess excellent properties along one of the above lines are defective in some other respect, so that as a whole the service which they render is not satisfactory.

The tests carried out by the Bureau of Standards included ones to determine the electrical resistance of the porcelain insulators under various temperature conditions, the gas-tightness of the plugs, and their ability to stand up under mechanical shock, beside actual tests under operating conditions in engines.

For the electrical tests of the porcelain, the actual insulator or a special cup-shaped specimen made from the insulating material was placed in a small furnace in which it was heated to a high temperature while at the same time the insulator formed part of an electric circuit. The temperature at which the material ceased to be an insulator under the given electrical conditions was thus determined. The tests upon the cup-shaped specimens are, in general, more satisfactory than those on the finished insulators, as the conditions may be more readily controlled.

In order to determine the gas-tightness, the complete spark plugs were screwed into a steel pipe connected with a source of compressed air. This pipe was immersed in an oil bath heated by electricity. If the plugs leaked under the air pressure, bubbles appeared at the surface of the oil. A graduated bell jar was placed over each plug and the displacement of the oil by the air in a given time could thus be determined. In this way, the leakage of completed plugs could readily be calculated.

A special machine was constructed for determining the resistance of spark plugs to mechanical shock. It consists essentially of a hammer into one side of which the spark plug is screwed. This hammer is dropped through a definite height upon a steel anvil by means of springs and a revolving cam mounted on a shaft and driven by a small motor. The blow was repeated a fixed number of times per minute and the spark plug which stood up the longest under these repeated shocks was considered to be the strongest mechanically. No laboratory tests can, of course, ever be as satisfactory as actual service on an engine in determining the suitability of such a device as a spark plug. This was recognized by the Bureau and the engine tests which it conducted were very complete.

In connection with the engine work done in the altitude laboratory, it was possible to investigate the behavior of spark plugs under the actual conditions met with in flight at high altitudes. Plugs were also tested in airplane engines under ground conditions and in typical automobile engines. Several reports have been issued on this subject in connection with the National Advisory Committee for Aeronautics and have been combined in the Fourth and Fifth Annual Reports of that Committee.

THE TESTING OF AIRPLANE RADIATORS.

LIKE the ignition system, the radiator is an extremely important portion of the aircraft power plant. It is true that a considerable number of such engines are air-cooled and thus are able to dispense with a water-cooling system entirely, but the typical airplane engine of today is, nevertheless, a water-cooled machine. There are some difficulties connected with the water circulating systems and radiators used on automobiles and these difficulties are magnified many times in the case of an airplane. The speed of the average motor car is not sufficiently high to warrant the making of any great effort toward reduction of wind resistance. If the radiator will cool the circulating water sufficiently to keep the engine at a proper working temperature when the car is moving at an ordinary rate of speed, it is all that is necessary. These requirements, simple as they appear, however, necessitate some care in the design of the radiator. They require the exercise of the highest degree of skill and the use of all the available information on the subject when it comes to the designing of a successful radiator for airplanes.

On air craft the elimination of every ounce of superfluous weight is of the first importance. This has resulted in the use of engines which deliver a very great amount of power for their size and necessarily results in an engine operating at high temperatures. The cooling of such an engine is in many respects a difficult problem even if it had to be accomplished wholly under the normal conditions existing at the earth's

surface. To successfully accomplish it, both when the plane is flying near the earth and when it is operating at high altitudes and low temperatures, requires, as before stated, the highest degree of skill. Then, too, the modern airplane travels at a very high rate of speed, often well over 100 miles per hour, and every bit of unnecessary head resistance ought to be avoided. It is probably not generally known that an unsuitable type of radiator, perhaps badly located on the plane, will absorb from 10 to 20 per cent or more of the total power of the engine, and where every bit of power should be made available for useful work, this is a serious loss.

Early in the war, it was evident that many types of radiators, not well fitted by design and construction for use on airplanes, were being employed on our machines. It was with the idea of discovering, if possible, the most suitable type of radiator for military airplanes that the Power Plants' Committee of the National Advisory Committee for Aeroanutics requested the Bureau of Standards to thoroughly investigate this problem. This work has been continued from May, 1917, when it was commenced, to the present time, and a great deal of extremely valuable data have been collected.

The Bureau has used in this work three types of wind tunnels and has received from the various radiator manufacturers over 100 specimens of their products. One of the wind tunnels is the large 54-inch tunnel constructed about two years ago. This tunnel is provided with two aerodynamical balances, one of which is rugged enough to serve as a mounting for specimens of radiator core. Within this tunnel have been determined the head resistance of the various specimens submitted. The flow of air through the radiators in terms of speed of the air stream has likewise been determined in this tunnel. The securing of this information was attended with considerable difficulty, but by means of a special small sized Venturi tube attached to the rear face of the radiator, it was successfully accomplished.

The two other tunnels are of small size and were used for the determination of the efficiencies of the radiators as cooling devices. The first of these tunnels which was constructed consisted of an air-tight tank within which was mounted a smaller wooden air passage open to the tank at both ends and in the center of which the specimen radiator core was placed. The same air was continually forced through the radiator and returned along the interior of the outer tank by a blower driven by a belt from an electric motor. As the entire outer tank was air-tight, the air could be withdrawn from it by means of a vacuum pump to simulate the low atmospheric pressure met with at high altitudes. Through the radiator core hot water was forced by a centrifugal pump and the rate of cooling of the water at a given air speed was thus determined. The air within the tank was cooled between each successive passage through the radiator, by means of a honeycomb mounted at one end of the wooden air duct. This tunnel was rather difficult to operate as a run required a number of hours due to the fact that it was a long while after the starting of the motor before stable conditions were reached within the tank. The second small tunnel was, therefore, built. This was entirely open and consisted merely of a wooden box-like structure, the passage through which was blocked by the radiator core. At one end of the air passage thus formed, a blower was placed serving to draw the air through the radiator. Instead of using water in the radiator core, superheated steam at atmospheric pressure was employed. It was found that the heat transfer could be determined as accurately through the use of steam as when using water, and a test could be carried out with this apparatus in a very much shorter time.

Through these tests on head resistance, air flow, and heat transfer, it has been possible to state what should be the principal characteristics of a satisfactory airplane radiator. It is obvious that low head resistance and high heat transfer are necessarily conflicting requirements and the most successful type of radiator to employ is the one which hits the happy medium between these two opposite extremes.

The Bureau has been able to assign a so-called figure of merit to each type of radiator tested. This figure of merit expresses the horsepower dissipated by the radiator in terms of the horsepower absorbed, and, therefore, states in briefest possible form the suitability of the devices for airplane cooling purposes. The results of the Bureau's work in this field have been included in the series of Aeronautic Power Plants Reports issued jointly by the Bureau of Standards and the National Advisory Committee for Aeronautics, and have been well received by most of the manufacturers of radiators. While particularly applicable to aircraft work, many of the facts discovered are of importance to the designers of this class of apparatus for motor car and other uses.

A NEW FORM OF VIBRATION GALVANOMETER.

VIBRATION galvanometers are very useful in a. c. null measurements, but have not been much used in industrial laboratories on account of their being sensitive to external vibrations and requiring delicate adjustments. The present instrument, which has a sensitivity higher than other forms of the moving-iron type, but less than that of the most sensitive forms of the moving-coil type, has the advantages of sturdiness, quick responsiveness, and freedom from the effects of external vibration. It consists essentially of a fine steel wire mounted on one pole of a permanent magnet and so arranged that the free end of the wire may vibrate between the poles of an electromagnet through which flows the current to be detected. The motion of the wire is observed with a microscope.

The "resonance range" is about one per cent; that is, if the frequency of the current is one per cent above or below the frequency of resonance the amplitude of vibration will be half as great as resonance. The sensitivity is such that with a 1-ohm winding an e.m.f. of 3 microvolts may be detected, and with a 270-ohm winding a current of 0.05 microampere can readily be detected.

TWELFTH ANNUAL CONFERENCE ON WEIGHTS AND MEASURES, 1919.

THE Annual Conference on Weights and Measures is a national organization composed of State and local weights and measures officials throughout the United States. This body meets annually at the Bureau of Standards, Washington, D. C., for the purpose of discussing and solving problems relating to weights and measures, such as uniform legislation, rules and regulations and methods of enforcement of weights and measures laws, specifications and tolerances for all commercial apparatus, and the proper inspection and test of apparatus, etc. The present meeting was the twelfth one held, and the first since 1916, the sessions having been discontinued during the war. This report, which is a stenographic record of the proceedings, includes all papers read and resolutions adopted. Perhaps the most important single accomplishment of this Conference was the discussion upon and the tentative adoption of a set of specifications and tolerances for liquid-measuring pumps, especially those used in the sale of gasoline, kerosene, etc. It was agreed by the members that these should be thoroughly studied and tried out in the field and that final action upon them should be taken at the next meeting. The unsatisfactory condition of liquid-measuring pumps in all parts of the country rendered action on this important subject imperative if the purchaser was to receive the correct amounts.

Consideration was also given to a number of other subjects of importance, including the progress made in the various States and cities; the necessity of the Federal regulation of type of apparatus; the proper method of sale of ice and wood; the testing of railroad track and mine scales; the marking of wrapped hams and bacon with the net weight; the standardization of shipping containers; and the adoption of the metric system of weights and measures.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

FUMES AND FOOD.

The statement has frequently been made that much of our industrial research has received its impetus from litigation or legislation which threatened the extinction of noxious waste-producing industries. In the vicinity of certain smelters co-operation among the farmers brought about a series of damage suits based upon injury to crops by smelter fumes, largely compounds of sulphur. A long series of experiments has convinced the smelter authorities that certain crops are damaged by the fumes, although in this case, as elsewhere, plots of the same material growing side by side were not always similarly affected by the sulphur fumes.

It has been known for some time how to utilize such fumes, as for example, in the manufacture of sulphuric acid, and had the smelters been located near the large consuming markets, this opportunity to make sulphuric acid cheaply would never have been overlooked. It has not been possible to ship sulphuric acid such distances and compete with manufacturers nearer the market.

A plan has been evolved, however, which seems to afford the long-desired solution. There are great deposits of phosphate rock to be found sufficiently near these smelters to allow it to be laid down at the plants for not over $5 a ton. In making super-phosphate fertilizer the usual practice is to use a ton of rock and a ton of sulphuric acid, producing two tons of super-phosphate. This material is sold on the basis of the available phosphate content and the treatment just mentioned does not produce an amount of phosphate which will stand the same long freight haul which makes the manufacture of sulphuric acid itself uneconomical at those points. By using a much larger quantity of acid the reaction with the phosphate rock can be carried to the point where syrupy phosphoric acid is produced and since the smelters can make sulphuric acid at a price reported to be about $5 a ton, they can of course use the large quantities necessary to carry through this last-named reaction. Now if a further quantity of phosphate rock is treated with this syrupy phosphoric acid, a double super-phosphate is produced which runs so high in posphate that it will stand transportation charges to carry it to a world-wide market.

There is a great demand for phosphates in Europe and in the Orient, as well as among our own agricultural states, and it would appear that the fumes which have long been a nuisance may now make possible the utilization of rich phosphate rock deposits which in turn will produce a marked increase in the world food supply.

THE ORGANIZATION OF INDUSTRIAL SCIENTIFIC RESEARCH.

The McGraw-Hill Book Company, Inc., has just published "The Organization of Industrial Scientific Research" by Dr. C. E. K. Mees, who has long been concerned in the study of such organizations and in putting into effect the results of this study. The book is intended to answer practical questions of the manufacturer who, having been convinced that the application of science is necessary for the progress of his business, desires to know the probable cost to establish and maintain such a laboratory, where a suitable staff can be secured, the lines of work that should be pursued, how soon and to what extent returns may be expected, how the laboratory should be organized, and what place in the established organization the new department should occupy. The book discusses the general question of research and how it should be conducted, its purposes and some of the results which have come from research, and then gives particular attention to types of research laboratories, coöperative laboratories, the position of the research laboratory in an industrial organization, the internal organization of industrial research laboratories, the staff of research laboratory, the type of building and how it should be equipped, and suggestions as to the direction of the work of such a laboratory. The entire discussion is illustrated with organization charts and diagrams which are very useful and serve to emphasize the points made in the text. As an example of how the principles discussed work out in practice, a chapter is devoted to the design of a research laboratory for a specific industry. Finally there is an extensive bibliography and an author's index, as well as an index of laboratories to which reference is made in the text, all of which will be found very useful.

A book of this character coming, as it does, from the head of a great industrial research laboratory, is welcome at this time when the establishment of research organizations and laboratories throughout the world is being taken up so seriously. There are a few men who have likewise studied this same problem, who are capable of giving sound advice on the subject; but we have had no adequate printed discussion previous to the appearance of this work, and it is to be expected that manufacturers in general will find in it a great deal of interest, helpfulness, and value.

PHOTO-CHEMISTRY.

Those who attended the lectures of the Eighth International Congress of Applied Chemistry will always remember the delightful and interesting lecture upon photo-chemistry by the Italian representative. The part which light plays in a host of chemical reactions has long been recognized, but not until recently has anyone ventured the statement that light has a more profound effect upon the growth of plants than does temperature.

W. W. Garner and H. A. Allard, scientists in the Bureau of Plant Industry, U. S. Department of Agriculture, have conducted exhaustive experiments which may prove of the highest importance in the future planting of crop systems for different regions eventually based no doubt upon the world requirements for food stuffs. It may even be found that the animal organism is also capable of responding to the stimulus of light, and experiments which have been conducted upon hens with artificial light may prove eventually to have been founded on much better scientific bases than the humorists have led us to believe.

Greenhouse experiments, according to an announcement of the Department of Agriculture, prove that the flowering and fruiting period of practically any plant can be made to take place at any time of the year by lengthening or shortening the day, as may prove to be required. This may be accomplished by darkening the house in the morning and evening to obtain a short day, or artificial light may be used to lengthen the period of light.

Heretofore we have considered temperature as the controlling factor deciding which were the spring flowers and to bring about the migration of birds, but it now seems that such phenomena may be a function of the length of the day. It has been found that some plants will not reproduce except when exposed to the favorable length of day, although too much day light for flowering and fruiting might stimulate profuse vegetable growth. When a length of day well suited to both growth and fruiting obtains, then we have the everbearing type of plant. The scientists quoted have forced cer-

tain plants to complete two cycles in one season and soy beans, exposed to the light for only five hours a day, flowered nearly three months earlier than plants left in the light all day. They attained only one-eighth the height, however. Iris kept in artificial light for eighteen hours a day bloomed in two months.

The new principle may explain why many plants grow so successfully near the northern limit of their range. In such latitudes the long day permits maximum vegetative growth, after which the short day intervenes and starts reproduction. That temperature seems to exert on the whole a far less influence is shown by the fact that plants kept in the dark for a part of the day could be made to undergo the changes of autumn in mid-summer, notwithstanding the fact that frequently the temperature of the greenhouse was higher than that outside.

Scientists have frequently been puzzled by the behavior of crops attempted in locations new to the plant, and it would seem that this influence of light may have been a factor of great importance to which full consideration was not given.

The chemist in his laboratory frequently reckons with light in conducting his experiments and apparently nature in her laboratory finds the need even more urgent. What a tremendous scope for new research is opened by these latest discoveries in photo-chemistry!

NAMES OF DYES.

In a recent number of the *Color Trade Journal*, Dr. J. M. Mathews describes in detail the basis for the present complicated nomenclature of dyestuffs and as synthetic dyes have come to occupy so large a portion of our attention, it may be well to give an outline of the evolution of these names.

In the beginning practically all dyes were given names intended to indicate some particular quality, such as fuchsine, malachite green, etc. Occasionally a color was named for some historical character, giving us Victoria blue and Bismarck brown. About the same time it became the habit to indicate by the name something of the use of the dye-stuff, and we have cloth red, chrome black, and acid magenta. The chemical nature of dyes soon became indicated by the name assigned, some of them, such as tartrazine, denoting the derivation, which in this case is from dioxy-tartaric acid. Methyl violet, diazo black, and azo rubine are examples.

As the number of synthetic dye manufacturers increased, they began to give very different names to the same product, in the hope that they might establish a proprietary or trade name which would be of value to them. For example, there are at least seven names for direct cotton blue, each name indicating a different manufacturer; the dye-stuffs are practically identical. Such a system could not fail to lead to great confusion and this has increased until manufacturers have now endeavored to systematize nomenclature by giving class names to the various lines of products. Thus, the sulphur dyes have received special class names as follows, each indicating a different manufacturer; sulphur colors, immedial colors, thiogene, katigen, kryogene, and thion. All of these are of German origin and the number has been increased by the establishment of new dye houses in Scotland, England and America. We now have Erie colors, pontamine colors, amanil colors, auwico colors, etc.

We frequently find numerals and letters occurring after the names of dye-stuffs, these being private marks used by the manufacturer in identifying the color. These frequently refer to the particular shade. Thus, B indicates a blue tone, R, a red one, G, green, and Y, yellow. Methyl violet B and methyl violet BB or 2 B, would indicate that the last-named is somewhat bluer in tone than the former. Acid yellow G and acid yellow R shows that the foremer has a greenish tone, while the red in the second gives more of an orange shade. X is used to indicate concentrated type. Then, we have W as the sign of a wool dye, S to indicate ready solubility, and L a type of dye fast to light. Where numerals are used, they indicate differences in strength. Auramine O means the pure strong type, while Auramine 1, 2 or 3, refers to dyes more and more dilute.

This would seem to be complication enough, but mixed dyes add another chapter. Thus, a green dye may have been made by properly mixing a yellow and a blue, each of which already had names of their own. Formyl blue B is a bright blue dye-stuff derived from formyl violet S 4 B, with a second dye so chosen as to give the desired blue in the final mixture. These mixed dyes have been necessary in order to meet the demand of the dyer who works largely from a standard color card.

The nearest attempt to a real classification and system of dye nomenclature is represented in dye-stuff tables compiled by Schultz, the last edition of this work being in 1914. There are of course many dyes which cannot be found in these tables, but they represent an effort in the right direction and eventually we may have some satisfactory scheme for identifying and maintaining familiarity with the large and ever-increasing dye family.

ANALYSIS BY ELECTROLYSIS.

A method for determining the percentage of carbon in steel, dependent upon the change of electrical resistance brought about in a standard solution by the precipitation into it of another substance, has been devised by J. R. Cain and J. C. Maxwell. It is claimed that the method is accurate to within .01 per cent. The substance precipitated in the standard solution is in this case the carbon dioxide obtained by the direct combustion of the steel. The standard solution is barium hydroxide of known electrical resistance. The equation involved is barium hydroxide plus carbon dioxide equals barium carbonate and water, and the increase in the resistance is due to the precipitation of the barium as carbonate. This principle is said to be new and the apparatus used is also unique. The method seems to offer many advantages for technical work over the methods heretofore employed for the measurement of electrolytic resistance. Former methods require a complicated and expensive set of apparatus, while the new method is much simpler. The nomograph is used for the graphical representation of the resistance data and the use of special conductivity cells with adjustable electrodes to facilitate the manufacture of any number of such cells without the same cell's being constant, is a new feature. The method is described in a recent issue of *Iron Age*.

GREASE RECOVERY.

The attention of many chemists has been turned toward the recovery of grease from various waste materials, usually by the solvent extraction process. The treatment of trade or municipal effluence containing grease is always a matter of economic interest and value, especially where wool textiles are manufactured. Doubtless a large part of the oils and fats used in the form of soap might be recovered from the sewage of towns, especially those in textile districts. There is a further waste of animal fats from kitchens and in the city of New York, where garbage has been sorted and graded with a view to the recovery of fats, revenue was produced even in pre-war times.

The solvent extraction process applied to oil cake of seed-crushing mills, has given us the second and third grade oils, but it has not been so extensively used on sewage and where other low-grade oils and greases might be recovered. Grease of this character has been recovered by acidification and steam pressing of the resultant magma, but independent reports now show that even this process has been carried on very indifferently in most instances. There appears to be one principle upon which the efficient and thorough extraction of grease may be said to depend, and that is by the use of a volatile solvent, which can then be recovered for re-use by the employment of a satisfactory still.

In England the process is carried on as follows: "Having

carefully arranged the perforated plates and canvas, the bottom door of the extractor is closed and jointed upon the extractor body. A charge of dry material is then fed through the top manhole into the extractor, and the manhole door carefully secured upon the jointing. The quantity of material which can be worked at a charge in a given extractor has been found to vary with the nature of the material. If the material contains a large proportion, say, 45 to 55 per cent, of mineral matter, such as sand and dirt, it is possible as a rule to work with an extractor 8 or 9 feet in depth and to have almost thorough extraction, because of the openness and stability of the material.

"With a material containing 25 per cent of mineral matter and a large quantity of organic matter in addition to grease, it may only be possible to work with a depth of 4 to 5 feet of material. This is because the material when saturated with the solvent tends to disintegrate and settle down into a compact mass upon the perforated plates, which, if a great weight of material is used, become choked, with the result that the upward circulation of the solvent and the passage of the grease downward into the bottom portion of the extractor are prevented, thus causing very indifferent extraction to occur. With material of this character it is necessary that the diameter of the extractor should be large in comparison with the height, so that the pressure of material on the perforated plates is not too great.

"The next operation is to run a volume of solvent, 100 to 150 gallons, from the storage tank into the lower portion of the extractor. Steam is then gradually turned into the closed coil and the solvent gently evaporates, rising through the perforated plates into the material and finally through it into the condenser. The liquid from the condenser then passes onward through the separator, the solvent returning to the storage tank. In this manner the whole mass of material becomes heated and saturated with solvent, and there is then a continuous percolation of grease dissolved in the solvent downward through the perforated plates and into the lower part of the extractor.

"Fresh supplies of solvent are admitted from the storage tank to the extractor from time to time, so that a steady stream of liquid runs into the separator. This process is continued for 6 to 10 hours, according to the weight and nature of the material; by this time practically the whole of the grease will have been brought down into the lower part of the extractor. Further additions of solvent are then discontinued, and the steam coil is gradually turned on full until the flow of solvent from the condenser almost ceases. The lower part of the extractor then contains a saturated solution of grease. This is next removed to the still by closing the vapor valve on the extractor and admitting a little open steam until a pressure of 2 to 3 pounds is shown on the gage. The valve on the pipe connecting the extractor to the still is then opened, and the grease solution is forced by the pressure from the extractor to the still. If the material is rich in grease, this blowing-out process may have to be carried out two or three times during the extraction process, as well as at the finish."

ENAMELLED APPARATUS.

In the journal of the American Ceramic Society, Mr. Emerson P. Poste discusses the manufacture of enamel-lined apparatus. It is difficult to estimate the importance of this class of material, not only in the chemical manufacturing plant and laboratory, but in the hospital and household. There are several rather distinct lines of manufacture, some of the iron shapes being coated with a vitreous enamel, built up by several coats, such as a ground coat and cover coats, and the glass-lined material now to be found in the form of tanks and more intricate shapes.

There is great need for technical control not only in the manufacture and application of the enamels, but in the preparation of suitable shapes upon which to place these burned enamels. Obviously over-burning and under-burning must be avoided. There are many questions of coefficients of expansion, uniformity of burning, etc., that are particularly important.

Enamels are usually made up on molecular formulas, and the article mentioned indicates a number of typical formulas. The raw materials which enter into the type of enamel usually placed upon a cast-iron or pressed steel shape may contain various proportions of some of the following: soda, borax, saltpeter, Chile saltpeter, lead oxide, zinc oxide, tin oxide, calcspar, barium carbonate, magnesium carbonate, feldspar, fluorspar, cryolite, quartz, manganese dioxide, and cobalt oxide. In addition, clay or sand is sometimes added in the mill in which the frit is ground.

The growth of the chemical industry has introduced many new problems in the manufacture of enamel-lined apparatus, for acid-resisting enamels must be used in apparatus to be provided with various complicated connections, stirring apparatus, and similar unusual equipment.

REFRACTORY MATERIALS FOR COKE OVENS.

The *British Clay Worker* gives some specifications relative to refractories suitable for coke oven construction. The special qualities required are: resistance to high, prolonged heating, either under normal or increased pressure; resistance to mechanical abrasion; resistance to sudden changes of temperature; impermeability to gases; and resistance to chemical attack, especially by sodium chloride at high temperatures. Fire clay brick are extensively used in England, because washed coal is fired into the retorts and this contains about fifteen per cent moisture. Fire clay brick are more resistant to moisture than are silica brick. In the United States the coals are either not washed or are partly dried after washing, and usually contain not more than five per cent of moisture, so that silica brick, which are superior in heat conductivity to fire brick, are used. The fire clay brick used in coke ovens contain a higher per cent of silica than most fire clays and are made by mixing a siliceous material with a high-grade fire clay.

In a satisfactory brick the silica content will not be less than eighty per cent, while ferric oxide should not exceed two per cent. The total alkali should be less than 1.3 per cent, with the lime and magnesia about 0.5 per cent.

Fine-grained material is generally less satisfactory than the coarser grained, and is less resistant to chemical attack. Coarse-grained material also withstands sudden changes of temperature better, and grain size obviously affects porosity, permeability, and heat conductivity. The finer grained refractories on the whole withstand mechanical abrasion the best.

By washing the coal with hot water most of the soluble salts, such as sodium chloride, are removed and the life of the refractory is thus prolonged. The fluxing effect of coals has been tested by heating pieces of fire clay in a small crucible with samples of the various coals. The fire clay is then washed free from the soluble salts and the percentage of alkali reckoned as potassium oxide determined, making due allowance for that present initially in the fire clay. In every instance the experiments with unwashed coal yielded a higher percentage of alkali in the clay and similar experiments to determine whether moisture favors the action of salts on coal show that it does materially increase such action.

UNSOUNDNESS IN CEMENT.

There has been considerable discussion in *Concrete* relative to the cause of unsoundness in Portland cement. According to the observations of R. K. Meade, an authority, it is difficult to make sound cement from raw material high in iron. Excess of fluxes is of little assistance in producing sound cement and the free lime in the porous clinker should hydrate in the 24-hour storage period of the test pat. It is the belief of Mr. Meade that neither the free lime theory nor the dusting clinker theory are entirely acceptable. The dusting clinker

is usually produced by a relatively high silica mix. High lime cements are very apt to be unsound and they also have the greatest quantity of cohesive constituents. Gypsum, plaster of Paris, or calcium chloride, added to the cement, often make it sound and concrete may become sound with age. As the author observes, many of the theories on cement are unsatisfactory, because while they explain some phenomena quite well, they fail entirely in the case of others.

PULVERIZED COAL.

IN the last issue of *Chemical Age*, under the title "Forecasting the Fuel of the Future," there is an interesting discussion of pulverized coal and its application. Many fields of usefulness for this grade of fuel were found: first, where in any one installation the fuel consumption is at the rate of not less than eighty tons a day; second, where an inexpensive source of low-grade fuel is available; third, where the character of the coal is such that it cannot be efficiently handled in the ordinary way, either because of its size or friability; fourth, where operating practice requires special facilities for heat control; and fifth, especially where gas is available for use with pulverized coal when peak-load conditions must be met.

The factors which have to be taken into consideration when burning pulverized coal in suspension are a sufficiently low velocity of fuel travel through the combustion zone in order that the complete reaction may take place, a refractory furnace which will assist in maintaining a proper temperature, the admission of air containing free oxygen, and the disposition of the gaseous products of combustion and of the ash. Any coal reduced to particles of a size to promote quickly the chemical reaction which we call combustion, and then passed through a zone of the right temperature, will burn satisfactorily in suspension, and this makes possible the efficient utilization of a great quantity of low-grade fuel which heretofore has not been drawn upon very extensively.

The principal points in the pulverizing of coal are given as follows: From the storage hopper coal is fed into a crusher that will produce lumps passing a three-quarter by three-quarter inch screen or smaller. The lumps are then passed over a magnetic separator, which removes stray iron which might cause trouble in the pulverizing equipment. The coal thus cleaned is stored and dried on its way to a dry coal storage bin, from which it feeds by gravity to the pulverizer. The rate of feed is controlled to prevent flooding the pulverizer, and after pulverizing, the coal goes again to a storage bin located as nearly as possible to the point of utimate consumption. It is to be seen, therefore, that the installation is a series of reservoirs, each of which should have sufficient capacity to permit operation irrespective of what takes place in the set of equipment immediately preceding it.

In the cement industry many millions of tons of pulverized coal have been handled by means of screw conveyors without damage and we must realize that pulverized fuel in mass is neither explosive nor highly combustible, and that danger is encountered only when, like other readily oxidizable dust, it is in suspension in air.

AMERICAN DRUGS.

IT is well known that we have depended upon the importation of crude drugs for nearly all of those used in pharmaceutical preparations. Comparatively little consistent work extending over long periods has been undertaken either with the purpose of introducing foreign drugs or of so improving domestic varieties that their potency could be increased. There have been a few exceptions to the general apathy toward American grown drugs and at the University of Wisconsin a pharmaceutical experiment station has been established.

The cultivation of medicinal plants for other than instructive purposes was begun there in the spring of 1908. Since then a number of other universities have begun the cultivation of medicinal plants with reference to their economic aspect and more lately, the cultivation of such plants on a commercial scale has been undertaken by certain pharmaceutical manufacturers. Another experiment embracing some twenty acres has been established under the auspices of the Institute of Industrial Research, where both the introduction of foreign medicinal plants and the improvement of domestic plants has been under study.

The experiments at Wisconsin are carried on in coöperation with the Federal Government, the state, and are supported by fellowships. Besides plant-breeding experiments and the growth of a considerable number of plants, experiments have been conducted with reference to distillation and other processes for obtaining values from the various crude drugs.

On the whole the possibility of providing several of the much needed drugs has been established, and the time has come when such experiments deserve extensive encouragement and substantial aid.

ZIRCONIUM.

THE unusual properties of zirconium and its compounds make the element an unusually attractive one for research and experiment. Zircite is being extensively used in refractories, especially unusual types of furnace linings and tubes for pyrometers. Ferro-zirconium is proving of unusual interest in the steel field now that it has been determined that zirconium and its alloys dissolve completely in the molten steel. The ferro-zirconium thus obtained has a very high strength and possesses qualities which make it desirable in the manufacture of armor or similar sheet metal for defensive purposes.

A recent number of *Foundry* quotes *Le Genié Civil* as follows.

"Armor made of nickel-zirconium steel having a thickness of 0.39 inch has shown the same resistance to the bullet as nickel molybdenum steel of 0.51 inch thickness or chromium steel of 0.63 inch thickness. The zirconium steel which has given the best results has the following composition. Carbon, 0.42 per cent; manganese, 1 per cent; silicon, 1.50 per cent; nickel, 3 per cent; zirconium, 0.34 per cent. It possesses a tensile strength of 250,000 pounds per square inch."

LOSS OF NUTRITIVE PROPERTIES IN CANNED GOODS.

IN preparing vegetables for canning the preliminary process of boiling, even though it may last a very short time, inevitably extracts a portion of the most soluble and most appetizing nurtitive principle. Recent experiments have been made, both at Waedenswill in Switzerland, and at Dahlem near Steglitz in Germany, with carrots, peas, beans, spinach, asparagus and cauliflower, to determine the percentage of loss and the best method of avoiding or reducing it. The conclusions arrived at in the two countries are in agreement and are thus summarized in the *Vie Agricole et Rurale.*

It is found advisable to complete the preliminary boiling or "blanching" *in as short a time as possible,* and to employ for this purpose an *autoclave* instead of steam. The percentage of loss of the dry extract amounts to from 5 to 15 per cent in boiling water, from 2 to 8 per cent in steam and only from 1 to 7 per cent in the autoclave. The pressure in the latter is only a quarter of an atmosphere and the period of boiling lasts for only a few minutes—a quarter of an hour at the most. The loss of nutritive matters is increased by the fact that upon being taken from the boiling water the vegetables are placed in cold water and sometimes even in running water.

It is advised that the first water in which the vegetables are boiled should not be thrown away but used to fill the cans before sterilization. It has also been suggested that the cold water in which the vegetables are steeped might be used in the autoclave so as to entirely avoid the loss of the most soluble and most delicate matters. In any case these liquids may be concentrated and used for making condensed soups with the addition of fats, and either milk or meat products.

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

SPARK GAPS.

In practice high alternating pressures are often measured by means of spark gaps; in most cases, especially when point electrodes are used, the relation between voltage and gap length must be determined experimentally on account of the luminous discharges from such points and leads. However, in case of cylindrical or spherical electrodes the sparking voltage may be expressed in terms of the dielectric strength of the air and of the dimension of the gap. By proper selection of the diameter of the electrodes the disturbing discharges can be avoided. The fundamental and exact equations of the sphere gap are not suitable for practical applications. These can be simplified by an assumption that the charges on the spheres are concentrated in two points, the position of which is such that they divide the diameter of each sphere harmonically. Then, neglecting the increase of capacity, resulting from the decrease of the electrode distance, we have the following relation:

$F = V\ (A + D)/A\ D$, where V is the potential difference between the spheres, D, their diameter and A, the distance between the spheres. The above relation holds good only for

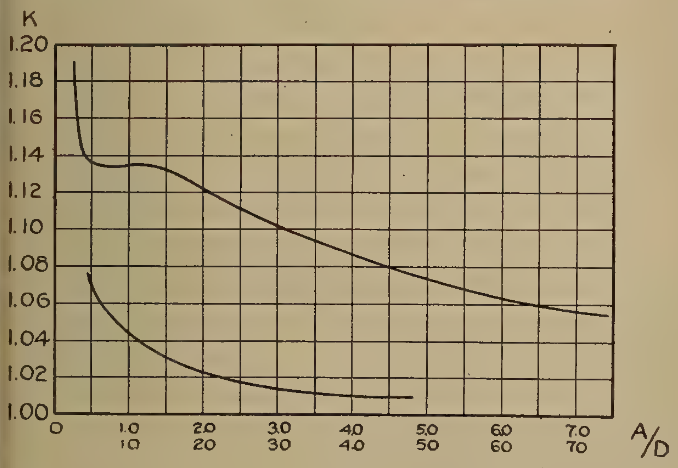


FIG. 1

spheres infinitely far apart; by comparing it with the exact formula of the spark gap a correction factor 1/K is determined which depends only on the relation A/D, and the above relation becomes

$$V = K\ F\ A\ D/A + D$$

The values of K are given in Fig. 1.

The potential distribution in the electric field was studied by immersing the spheres in an electrolyte, thus avoiding the various field disturbances. Spheres were used of 0.3 to 15 cm. in diameter with gap distances from 10 cm. to 40 cm. The experimental results agreed well with the calculated values. This method of investigation allows also of determining the influence of leads. The length of leading in wires of 0.7 mm. diam. was varied from 0 to 50 cm.; it was found that the potential gradient at the surface of the sphere was practically independent of the length of the leads; however the influence of the latter becomes noticeable at a short distance from the surface and is greater in the case of small spheres.

The problem of the sparking voltages between spherical electrodes was investigated by means of a 20 kw. transformer having a ratio of 500/200,000; the voltage was measured on the low-pressure side by a specially designed and well described and illustrated instrument which the author calls an "oscilloscope." It was found that the spark voltage is entirely independent of the wave form and is only a function of the maximum pressure. The values of the spark voltage for the various spheres and gap distances were reduced to normal pressure and temperature on the assumption that the spark voltage varies directly with the atmospheric pressure and inversely with the absolute temperature. From these data the dielectric strength of air in kilovolts per cm. is found to be a function of the sphere diameter and almost independent of the gas, as shown in Fig. 2.

From these data the breakdown voltage of a gap of A cm. between spheres of diameter D may be found from the relation given above. The error is from 1½—3 per cent within the range A/D = 4 to ½.—*W. Estorff, Zeitschrift für Instrumentenkunde*, July, 1919, pp. 227-30.

SUBMERSIBLE ELECTRIC MOTOR PUMP.

In the January issue of the Scientific American Monthly we described a new type of electrically-driven pump which is rendering very good service in marine salvage operations. The unique feature of this pump is that the electric motor will work entirely submerged under water and that the whole casing is filled with water while running, thus rendering it peculiarly suitable for use in flooded or damp places, such as mine workings, for example. It is entirely free from the risk of breakdown inherent in all so-called water-tight electric motors which depend on the efficiency of the joints and

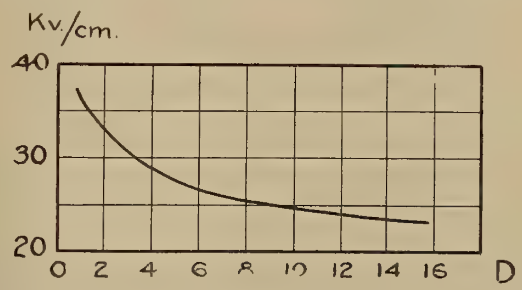


FIG 2

glands in the cases or tanks in which such motors are enclosed.

Recently some interesting operations have been successfully carried out in Cheshire, mainly with the object of demonstrating the possibilities of this pump for mine work. These operations consisted at first in the unwatering of an abandoned mine-shaft. The plant consisted of two 4-in. submersible motor pumps, each of which had a rated output of 370 gallons per minute at 80 feet total head. The delivery side of one pump was coupled to the suction side of the second pump, thus forming the equivalent of a two-stage centrifugal pump capable of a lift of 160 feet. The electric power was supplied by a portable generating set. Armored flexible rubber hose was used for the pipe line.

In another case three shafts linked together by workings had the water level 11 feet from the surface, and it was desired to lower the water to about 300 feet. In this case the power was supplied from the near-by company power plant. Four 6-inch submersible motor pumps were used, each having a rating of 740 gallons per minute at 75-foot head. They were coupled in pairs, the first pair being lowered to a depth of about 310 feet and the second pair to 150 feet. Steel tube was used for pipe line. After pumping continuously for five days

the water level was lowered to 160 feet and after a further seven days to 275 feet. Instructions were then given to throttle delivery and maintain a constant level at this depth, and readings taken of the inflow which commenced at 47,000 gallons per minute and dropped to 33,000 after three days. Altogether the plant was running for 37 days, one pair of pumps running for 24 days on end and on 19 of these days for the whole of 24 hours. The total quantity of water pumped was 33,623,604 gallons. This novel undertaking has thus demonstrated the great use which may be made of the submersible motor pumps in places where an installation of ordinary pumping plant would be impracticable, or, at any rate, very costly.—From *Colliery Guardian*, London, January 16, 1920, p. 173.

NEW METHOD OF MEASURING HEAVY DIRECT CURRENT.

THE usual method of measuring direct current with a millivoltmeter and shunt becomes unsatisfactory whenever the measuring instrument is at a considerable distance, 200 yards or farther, from the heavy current cable: the leads must be of large cross-section in order that the drop in them may be a minimum; even then the voltage drop which must be provided across the terminals of the shunt is so high that there is a serious loss of energy in the shunt. If measurements are to be over still longer distances, the cost of pilot leads and the loss in the shunt become almost prohibitive.

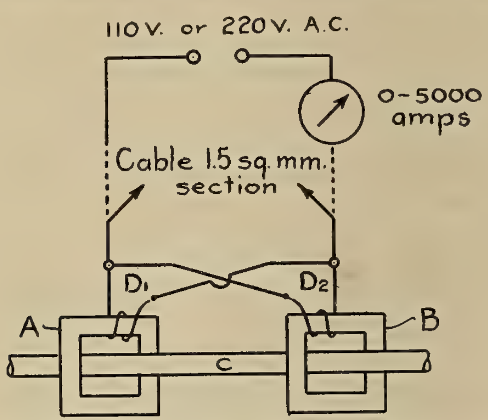


FIG. 3. METHOD OF MEASURING HEAVY DIRECT CURRENT

In order to overcome these difficulties, reliance has been placed in the past upon telephonic communication of instrument readings, or upon the use of repeating instruments of various kinds.

A novel method of measuring heavy direct currents at a distance has been devised by Ernst Besag and is now in use at Frankfort-on-Main. The method depends upon change in the choking effect of a choking coil fed with alternating current, when the iron core of the coil is magnetized by the direct current to be measured as well as by the alternating current.

Referring to the diagram, the heavy-current conductor, C, is surrounded by two iron ring-cores, on which are wound the coils D_1, D_2. These coils are connected so that there is no resultant effect on the current in C due to transformer effect from the alternating-current windings. The terminals of the latter are connected to the distant station, as shown and an alternating-current ammeter is placed where the current indications are required; A. C. supply at 110 volts or 220 volts is connected to the measuring circuit. When there is no current flowing in C, the coils D_1, D_2 exert an almost pure choking effect, and the A. C. ammeter reads practically zero. As the current in C increases, so does the magnetic saturation of the cores A and B, hence the choking effect of D_1, D_2 decreases, and the alternating current in the measuring circuit increases. For each value of the main direct current there is a definite value of the alternating current, hence the A. C. ammeter may be calibrated to read directly the direct current in amperes. By using a pressure of 110 or 220 volts in the A. C. circuit, the requisite current may be kept so low that quite small leads may be used without introducing any appreciable error from the voltage drop in these conductors.

Apart from its value in long distance measurement the new method eliminates the shunt losses, affords the possibility of the pilot lead to be insulated only for 110 or 220 volts and reduces operating risks by eliminating direct electrical connection between the switchboard and the high-voltage D. C. circuit. An important possible application of the new method is to the measurement of charging or discharging current of cells in a distant battery substation.

A possible modification of this method which suggests itself would be to use a single iron core round the heavy D. C. conductor, say, A, of diagram, and to connect a winding D, on this core to a fluxmeter. The fluxmeter being set to zero when no current was flowing in C, the deflection of the instrument should be a function of the current flowing in C. The flow would not be linear owing to magnetic saturation of the iron core, but it would be practicable to calibrate the fluxmeter to indicate directly the corresponding value of the main current. This modification would not be applicable to long distance measurement, owing to the very small E.M.F.'s produced by changes in the magnetization of A, but it may have its application in certain special cases, and, if so, it would offer the advantage of eliminating the A. C. supply required by Besag's method.—From *Elektrotechnische Zeitschrift*, Condensed in *Electrical Review*, London, March 5, 1920, p. 292.

MAGNETIC AND ELECTRICAL PROPERTIES OF IRON-NICKEL ALLOYS.

THIS investigation was undertaken to determine whether any iron-nickel alloys could be found having a higher saturation value than pure iron. Alloys were prepared containing 0-100 per cent of nickel. Pure Fe-Ni alloys do not forge readily, and to make them forgeable it is necessary to add alloying elements like Mn or Ti. The results show that the saturation value decreases slowly with increase in Ni content up to 20 per cent, then rapidly to 30 per cent; again rises rapidly to 50 per cent and falls off gradually toward 100 per cent nickel. At no point does it exceed that of pure iron. For values of H between 100 and 400 the permeability is about 5 per cent higher for 6 to 8 per cent Ni than for pure iron, but this advantage is offset by the large increases in hysteresis loss. Alloys containing 35 to 70 per cent Ni have high permeability at low and medium densities and low hysteresis loss, the highest permeability occurring for 50 per cent. 30 to 50 per cent alloys are characterized by a nearly straight line B-H curve from the origin to B = 2,000 to 4,000 gausses and also by low retentivity and coercive force properties which are of value in connection with certain electromagnetic meters.

Previous investigations on commercial iron-nickel alloys have shown that 25 to 35 per cent alloys have irreversible magnetic and electrical transformation points occurring below ordinary temperatures. The present investigation confirms these results for pure alloys. A 30 per cent alloy annealed and cooled to room temperature had its saturation value, 4π Is, increased from 2,500 to 17,000 gausses and its electrical resistance decreased from 81 to 32 microns per cu. cm. after being cooled to liquid air temperature and reheated to room temperature. Alloys containing 15.35 and 15 per cent nickel showed practically no change after the above treatment. After allowing all transformations from the austenetic state to the α state to take place the curves for 4π Is and for electrical resistances both have definite cusps for 34.5 per cent nickel, corresponding to the compound Fe_2Ni, thus giving evidence of the existence of this compound. It is pointed out that the irreversible transformation causes an enormous increase in the hysteresis loss.—T. D. Yensen, *Journal of the American Institute of Electrical Engineers*, April, 1920, pp. 396-405.

CENTRAL-STATION SERVICE FOR FARM LIGHT AND POWER.

According to estimates by Professor G. F. Warren, of Cornell University, the abandonment of farm life in favor of city life by men and boys during the past year has left more than 24,000 habitable farm houses vacant in New York State alone. This exodus from the farm has taken place despite the fact that farm wages will be approximately 14 per cent higher this year than last. It is evidently the city comforts in general and the electrical comforts or conveniences in particular that are largely responsible for people leaving their farm homes. The leadership of this country in world industry depends largely upon the number of progressive farmers who take up and continue modern methods of agriculture. American farms of the future must be equipped with electrical devices if they are to retain the high standards of living we now enjoy. Modern farms will appeal to the brightest of our youth and insure that the direction of the farms will be in competent hands.

The problem of supplying light and power to rural consumers from transmission lines may be considered as being just graduated from the experimental stage. Indications are that a large number of central station companies intend to do extensive work in this field during 1920. Behind it is the insistent demand of the farmer for such service who has seen the drawbacks of the small individual plant and the advantages of the transmission line service whenever the extension of this service is possible. The advantages claimed for transmitted power in comparison with individual plant include less ultimate investment, unlimited supply of power, 24-hour service, use of standard 110-volt appliances, no attention required, no house or barn space required, no acid fumes, smoke, gas, dust or noise, and no oil or gasoline to explode or catch on fire.

The problem, however, is to finance the installation of lines and to make their operation a success; that is to provide lines and equipment at a moderate price and so operated that they will not interfere with the service to municipalities. In the past the central station has financed the entire operation and assumed all risks when setting the rates. Experience has shown that those rates were usually set too low, with a consequent dissatisfaction with this class of service. The established practice at present is to require the farmer to finance the installation lines and the substation equipment. Risks are eliminated wherever possible and the rates set high enough to cover the balance of the contingencies. The tendency is to meter on the high-tension side so as to eliminate the uncertainty of the core losses and their effect on the rate schedule. The country banker must learn to extend credit by virtue of which the farmer can purchase these electric labor saving devices and conveniences, for by so shouldering the responsibility on the farmer, this field becomes financially possible.

OPERATING FEATURES OF FARM LINES.

With the responsibility shouldered on the farmer the equipment must be inexpensive but by no means cheap. The line construction is substantial so as to reduce the chance of line failure resulting in service interruption and liability for injury. The type of construction adopted, while not considered good enough for the more important trunk lines, is nevertheless very satisfactory for farm line service. As to primary pressure, voltages of 2,300, 6,600 and 13,200 have come into extensive use. Experience shows that the 2,300 and even 6,600 are too low, as the extension of farm lines naturally leads to the serving of small towns. It now appears that the standard line voltage for rural service will be 13,200. The farmer will finance the latter as readily as a lower voltage line. The advisability of using the higher line voltages may be seen from the fact that with 6,600 volts an area is served which is approximately nine times the size, and with 13,200 volts an area approximately thirty-six times the size of the area that can be served with 2,300 volts. As to systems, the ground single-phase type, the metallic single-phase and the three-phase four-wire systems have been tried and found unsatisfactory. The three-wire three-phase system has been extensively used and undoubtedly is the most satisfactory one. A combination of this system for the main artery and metallic single-phase lines for short laterals is the logical system to use. This system gives less severe operating conditions for fuses, oil switches and lightning arresters and has the advantage that it can be operated temporarily with one wire grounded. It, therefore, requires less tree trimming, which is quite a factor in rural service.

The question of farmers' substations is perhaps more important than other problems of line construction. As the farm lines are extended the importance of continuous operation becomes more pronounced. In the past this factor has often caused central-station companies to refuse service to farmers even with a line running in front of their homes. With a substation properly designed the fear of the hazard of interference with the continuous operation of the line is dispelled. The requirements of farmers' substations are as follows: (1) It must be inexpensive, but not cheap. (2) While inexpensive it must perform all the functions of a larger outdoor substation with a reasonable factor of safety. It must have full switching, lightning protection and overload protecting features. It must operate with the same degree of security against service interruption, but in case of failure it must be discontinued at once from the line in order that the trouble may be localized and prohibited from disturbing the whole system. (3) It must be safe; there should be but very little wiring and it should be so arranged that when the switch is open all equipment is readily accessible. (4) The factor of safety of the insulators should be high.—H. W. Young and F. C. Van Etten in *Electrical Review*, Chicago, March 20, 1920, pp. 483-85.

ELECTRICALLY-BAKED BREAD.

In localities where coal or other forms of fuel are scarce or dear the electric oven can be considered a serious competitor to the coal-heated oven. Electric ovens are on the market which are entirely satisfactory from the standpoint of technique, ease and safety of operation; moreover, the central station grants the baker very low rates for night operation of his electric ovens. In Switzerland the electric oven usually has an area of 6 or 12 sq. m. per floor, giving space for 16 to 18 kg. of bread per square meter. With loaves weighing from 0.5 to 1 kg. the baking takes one hour; with loaves weighing 1.5 to 2 kg. the baking period is one hour and a quarter to one hour and a half. The average amount of power required is 6 kw. per sq. in.; this permits the heating of an oven of 12m^2 in area in 1½ hours. During the baking period the power consumed varies from 50 to 60 per cent of that used for preheating. Below are given some data for one installation.

Hours of operation	Kg. of bread	Kw.	—Kw.-H. consumed— Total	Per Kg. of bread
1.5		72	108	
3.25	200	36	171	0.86
5	400	36	234	0.59
6.75	600	36	297	0.50
8.5	800	36	360	0.45
10.25	1,000	36	423	0.42
12	1,200	36	486	0.41

The manufacturers guarantee a consumption of 0.45 to 0.5 Kw-h. per kg. of bread. The initial cost of installation in 1918 was from 1,200 to 1,500 fr. per square meter—not any higher than for a first-class modern steam operated oven. It is further estimated that with coal selling at 10 fr. per kg. and electricity selling during night hours at 0.05 fr. per kilowatt-hour, economies will be effected with the electric oven.—From *Bulletin de l'Association Suisse des Electriciens.* Abstract in *Revue Générale de l'Electricité*, January, 1920.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

AMERICAN COMPETITION WITH BRITISH TRADE.

THE subject is discussed in *Engineering* (London) in an editorial under the title, "The Question of American Competition."

The paper calls attention to the sales efforts of American concerns in Europe, such as the fact that a leading American locomotive firm is alleged to have sent a representative to The Hague where he offered to quote prices not only on locomotives and other railroad equipment but also for all kinds of machinery including machinery for treating sugar, rubber, coffee and cocoanuts in tropical countries.

On the other hand, it is stated that in the calendar year of 1919 the American exports decreased while the imports increased, the reduction being due to the fall in the quantity of semi-finished steel sent out of the country for the account of Allied nations.

The imports increased through purchases of scrap and pig iron. (The statistics refer, of course, exclusively to the metal and machinery trades.)

If the American statistics are contrasted with those for Great Britain, it is found that the British exports showed a recovery for the first year after the end of active hostilities. The exports rose from 1,618,000 tons in 1918 to 2,254,000 tons in 1919, being an advance of 636,000 tons, giving a net balance of 360,000 tons to the advantage of Great Britain. The figures in the case of machinery are also hopeful for Britain, although a strict comparison between the latter and the United States cannot be made. The British exports advanced in tonnage by 65 per cent as compared with the preceding year.

As regards the future, it is stated that American steel and machinery makers have secured a great hold on international markets under the abnormal circumstances of a world-wide war and thereby became abnormally enriched. Furthermore, though peace prevails, the conditions throughout the world have not become normal and probably will not do so before another few years have elapsed. There is a great international demand for iron, steel and different classes of machinery in various countries and it is believed that Great Britain will obtain its fair share of this world trade as in former years. In fact, figures appear to show that it has already been able to make a fresh and favorable start in the resumption of its former position in the markets of the world, though the present high prices tend to facilitate American competition in external markets, except where the rate of exchange exercises an unfavorable influence upon prospective customers. Nevertheless the amount of work available in the world is so enormous that international competition to secure it should be inconsiderable for a long time to come.—*The Engineer*, Vol. 129, No. 3349, March 5, 1920, pp. 249-250.

NO FISSURES IN OLD RAILS.

A REPORT by W. C. Cushing, Chief Engineer of Maintenance, Pennsylvania Lines West of Pittsburgh, gives an interesting sidelight on the cause of the appearance of transverse fissures.

This report covers an investigation of rails which had been in service from 10 to 45 years; some of the oldest were of wrought iron, others rolled from iron and steel pile, while others 10 to 25 years old were of Bessemer steel.

In the old wrought-iron rails, head strains corresponding to 24,000 to 27,000 lb. per sq. in. in compression were found, which appeared the more serious because the material had a low elastic limit, 26,670 to 48,760 lb. per sq. in. The piled rails showed maximum head strains of 24,000 lb. per sq. in., and the elastic limit of the material ranged from 33,700 to 58,830 lb. per sq. in. Still higher internal strains, however, were found in steel rails that had been in service 20 to 25 years, several measurements of 36,000 to 33,000 lb. per sq. in. being made, as against elastic limits of 46,500 to 58,450 lb. per sq. in. These high values of permanent strain were measured at the surface of the head and on the side opposite the gage side, in nearly every case. One abnormal result was a reading of 57,000 lb. per sq. in. tensile stress, in the flange of an 85-lb. rail that had been in service from 1898 to 1917; Mr. Cushing calls this "extraordinary and inexplicable."

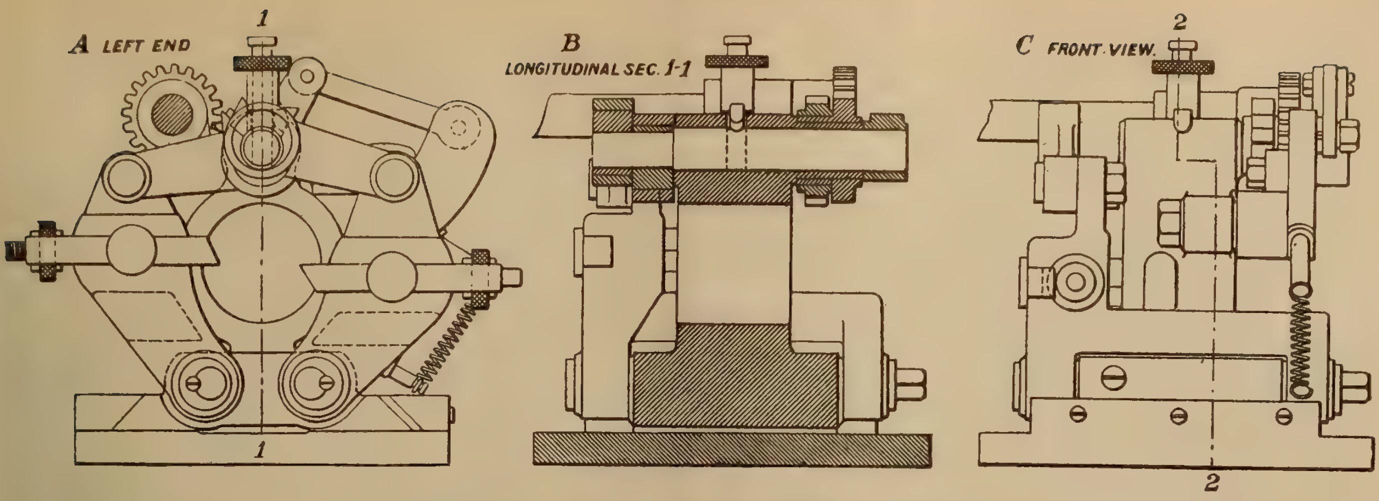
From a knowledge of the service to which these rails were submitted one would expect to find them filled with transverse fissures. In fact rails adjacent to them and undergoing precisely the same condition of service had been found to contain such fissures, which would indicate that the difference in the behavior of the two classes of rails must be sought in the process of manufacture.—Report No. 84 to the Rail Committee of the American Railway Engineering Association, abstracted through *Engineering News-Record*, Vol. 84, No. 11, March 11, 1920, p. 527.

AERIAL TRANSPORT OF WOOLEN GOODS.

OWING to the congestion of traffic at Hull Docks and to the dockers' strike at Amsterdam, the transport of goods from the Midlands to Holland, which has been taking the preposterous time of from six to eight weeks, has, for the meantime, become quite impossible. For this reason Messrs. Heatons (Leeds), Ltd., who do considerable business with Holland in ladies' clothing, decided to despatch by aeroplane a quantity of goods which they were anxious to deliver in Holland in time for the spring season. A Blackburn "Kangaroo" commercial airplane was therefore chartered from the North Sea Aerial and General Transport Company, of Leeds, to convey 22 packages, with an aggregate weight of over 1000 lb. to Amsterdam. The machine was loaded at Brough aerodrome, near Hull, on Friday, March 12th, and proceeded to Lympne, near Folkestone, for examination by the air-port authorities and thence to Soesterberg aerodrome at Amsterdam, where it arrived safely on the following day. The Dutch customs authorities arranged to examine the cargo immediately on its arrival, so that the packages could be despatched to their final destinations with little or no delay. The machine was expected to return with a valuable cargo of dyes of a class urgently required in Yorkshire and Lancashire. It is hardly necessary to point out that the commercial value of the service would be greatly augmented if the visit to Lympne for customs examinations could be avoided. Lympne is, at present, the only recognized point of departure for Continental aerial traffic, and this fact is obviously a severe handicap on aircraft travelling from the northern counties to Holland and the Baltic. Evidently the traffic would be greatly facilitated by Government recognition of an air station on the North Sea coast, since a direct flight across the North Sea could be made in half the flying time, and in much less than half the total time, owing to the fact that the long southward diversion renders a night's stay at Lympne unavoidable.—*Engineering*, Vol. 109, No. 2828, March 12, 1920, p. 344.

RELIEVING ATTACHMENT FOR LATHES.

IT is usually considered to be uneconomical to make milling cutters and other small tools in a general engineering shop,



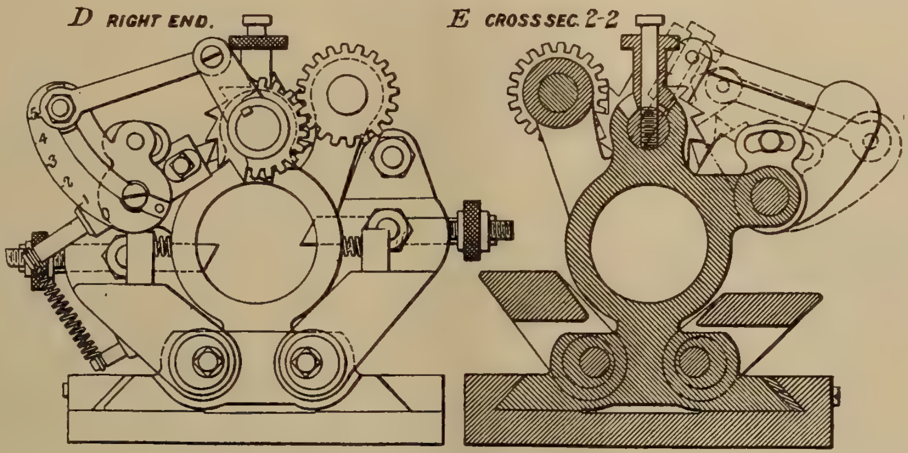


FIG. 1. MILTON RELIEVING ATTACHMENT FOR LATHES

but occasions arise when it is desirable to do so.

All the equipment necessary to make such tools is usually available in shops, but difficulty arises in connection with the work of backing off or relieving the teeth of the cutters. The teeth can, of course, be formed by milling with special cutters, but the ordinary shop cannot have all the cutters required for different shapes and sizes of tools. A relieving lathe which might be employed is likewise an expensive tool of very little general utility and it would not pay to have one to take care of an occasional odd job.

From this point of view the attachment described here and built by Milton, Ltd., London, is of interest. It is intended to take care of just the kind of job that can be usually done only on a relieving lathe or by means of special tools.

Drawings, Fig. 1—A to E, illustrate the construction of the attachment. It is mounted on a gibbed plate which is screwed upon a lathe saddle. Into this plate is fitted a steel casting having a hole through which the work passes, or the arbor on which the work is mounted between the centers of the lathe. There are also two oscillating tool posts carrying tools which can operate simultaneously on the front and back of the work, though for relieving, the front tool only is employed. Provision is made for adjusting the tools in a vertical direction to allow for any alteration in height which may have been introduced by grinding—likewise for the transverse adjustment of the tools. The tools themselves fit in slots in the tool posts and are each clamped in position by a bolt and nut.

The tool posts are rocked by means of two eccentrics mounted on a central shaft passing through the upper part of the main casting as shown in Fig. B. These eccentrics which are connected to the tool posts by means of short links shown in A are set at an angle of 180 deg., so that angular motion of the shaft will cause both the tool posts to advance into or recede from the work together. Mounted loosely on the opposite end of the central shaft bearing is a gear wheel, and on a sleeve extending from the boss of this wheel is screwed a ratchet toothed cam seen in Figs. A and D. The cam is driven from the nose of the lathe by means of a shaft having two universal joints. The cam rotates at the same speed and in the same direction as the work and must have the same number of teeth as the tool being relieved. The actual diameter of the cam and the shape of the teeth are immaterial, but the teeth may be formed with feather edges. Reamers and cutters in which the teeth are unequally spaced can be relieved by means of the attachment but in such case the teeth of the cam must, of course, be spaced to correspond with those of the work.

Referring now to Fig. D. (in Fig. 1) it will be noticed that the teeth of the cam engage with an adjustable pawl mounted on one arm of a bell-crank lever, which is pivoted on the main casting. As the cam rotates in an anti-clockwise direction the arm of the bell-crank lever will be pulled downwards until the pawl escapes from the tooth of the cam, when it will be pulled up into engagement with the next tooth by the action of a light helical spring seen in both illustrations. The combined effect of the cam and spring is thus to impart an oscillating motion to the bell-crank lever. On the other arm of the latter is formed a segmental groove, and in this groove a block, to which a short link is pivoted, can be clamped in any position. The other end of the link is connected to an arm keyed upon central shaft, above referred to, and in this way the oscillating motion of the bell-crank lever is communicated to the central shaft, and also, through the eccentrics, to the tool posts. Two short springs fitted between projections on the forked parts of the tool posts and the main casting are provided in order to take up any lost motion due to wear of the links, etc.

It will be obvious that the position of the block in the segmental groove determines the magnitude of the angular oscillations of the central shaft, and consequently those of the tool posts, so that, by adjusting the block, the amount of relief can be varied at will quite independently of the shape of the cam. The actual amount of relief is indicated by a scale engraved on the arm of the bell-crank lever, as shown in Fig. D, the figures giving the amount of relief in millimeters. The only other feature of the mechanism now remaining to be explained is the means provided for limiting the backward movement of the tools in normal working, while allowing them to be brought back clear of the work before reversing the motion of the saddle to commence a new cut. This arrangement is best shown in the cross-section, Fig. E, from which it will be seen that a bolt fitted with a sliding sleeve is screwed

into the middle of the central shaft. A tongue formed on the sliding sleeve fits into a slot in the main casting, and normally limits the movement of the shaft by coming into contact with the end of the slot, but when it is desired to withdraw the tools from the work the tongue is pulled out of the slot by raising the sleeve. This allows the spring attached to the bell-crank lever to pull the latter back into the position indicated by the dotted lines in Fig. E. In this position the tools will be quite clear of the work and the pawl clear of the cam; the lathe can then be reversed without altering the adjustment of the tools in the tool holders.

An important advantage of the pivoting tool holder in comparison with the horizontal slide of the ordinary relieving lathe, is that, in the former, the tools can be adjusted so that the cutting angle remains constant at all parts of the cut, and consequently greater cutting efficiency is attained and a tool with much less clearance can be used. That it is necessary to tilt the tool for this purpose will be obvious when it is remembered that the normal to the relief curve at the cutting edge of the tooth being formed coincides with the radius of the plain cylindrical blank, since no metal is removed from this part of the tooth, whereas, at the inner end of the curve, the normal is inclined by an amount depending upon the amount of relief. In an ordinary relieving lathe, in which the tool moves horizontally, no allowance is made for this feature, and the cutting angle may therefore vary by 15 deg. or 20 deg. from one end of the relief curve to the other. Another advantage of the pivoted tool holder is that the friction is considerably less than that of a sliding holder, and a greater part of the power supplied is available for the cut.—*Engineering*, Vol. 109, No. 2828, March 12, 1920. pp. 345-346 and 348.

THE HOLZWARTH GAS TURBINE SINCE 1914.

By Hans Holzwarth.

In 1914, a few months before the beginning of the war, tests were started on a 1000-h.p. vertical gas turbine built by the machine company, Thyssen & Co., in Mulheim (Ruhr). During the war these tests were discontinued and started over again in 1918. The Thyssen turbine does not differ in external appearance from the gas turbine previously built by the author at Mannheim, but in several particulars the Thyssen turbine differs from the Mannheim one.

HIGHER CHARGE AND EXPLOSION PRESSURES.

This was done to increase the output per cubic unit of chamber capacity and the thermal efficiency. The average explosion pressure for continuous operation was raised to from 12 to 14 atmos. abs. as compared with 5 to 6 atmos. abs. of the Mulheim turbine.

There is fundamentally nothing in the way of raising this pressure still higher by increasing the charge pressure above 2.3 atmos. abs. The curve of Figs. 2 and 4 show the influence of the charge pressure and explosion pressure on the efficiency and specific output of the turbine.

REDUCTION OF THE PERIOD OF EXPANSION.

The shorter the time taken by expansion the less the loss of heat to the chamber and nozzle walls and the greater the amount of heat transformed into kinetic energy, and, hence, the greater the efficiency. At present the duration of the period of expansion in the gas turbine is around 0.1 sec. In large gas engines running at 90 r.p.m. the expansion lasts about 0.33 sec., while in aircraft engines in which the heat consumption is not materially inferior to that in Diesel engines, it is 0.02 sec. at 1500 r.p.m. Fundamentally, there is nothing in the way of reducing the expansion period in the gas turbine still more. To do this the nozzle cross-section must be increased and this carries with it the increase in the length of the turbine blades and flow resistance.

CHANGES IN THE BLADE SHAPES AND BLADE FASTENINGS.

Decrease in the period of expansion provides an increase in pressure on the blades. Furthermore, unlike what takes place in steam turbines, the jet in explosion turbines acts intermittently for short periods and is of the character of a blow. Because of this, blade shapes and fastenings used, for example, in Curtis turbines would not be satisfactory. New blades, therefore, had to be developed which were planned to withstand the added stresses much better.

As regards the material of the blades, many kinds of al-

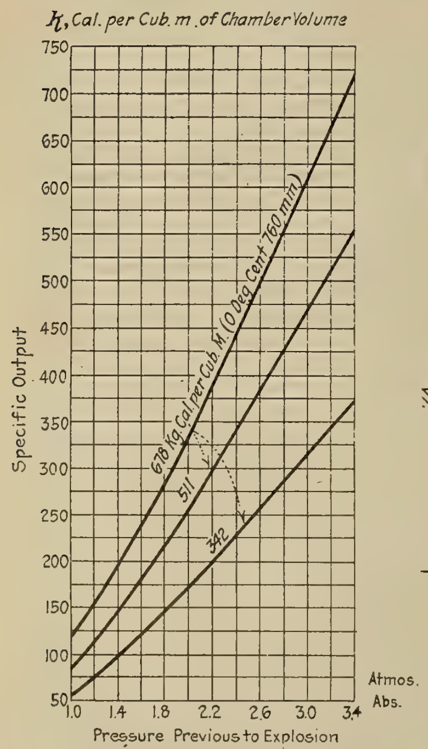


FIG. 2. INFLUENCE OF CHARGE PRESSURE ON EFFICIENCY

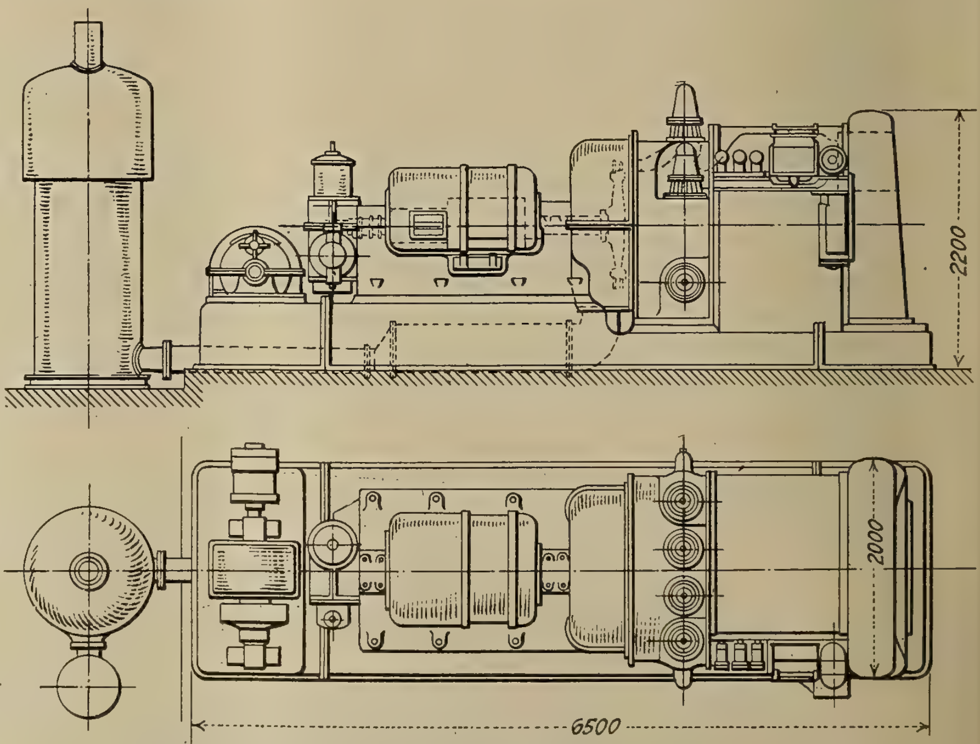


FIG. 3. GENERAL OUTLINES OF THE HORIZONTAL TYPE OF HOLZWARTH OIL FUEL GAS TURBINE 500 H.P. AT 3,000 R.P.M.

loyed and unalloyed hard and soft steels were tested with rather unsatisfactory results, and finally a soft electrolytic iron was adopted. With proper heat treatment blades of this iron proved to be very satisfactory for use in gas turbines. Table 1 shows the physical properties of this material from tests made in the testing laboratory of the Technical High School at Stuttgart.

On the other hand, blades made out of harder or alloyed steels show very rapidly changes in the structure of the metal,

Table 1

PHYSICAL PROPERTIES OF ELECTROLYTIC IRON USED FOR GAS TURBINE BLADES.

		—Tested at—	
		Room Temperature	450 deg. Cent.
Yield Point	kg. per sq. cm.	4204	
		3185	1975
Breaking Load	kg. per sq. cm.	4510	2675
Elongation	per cent	27.2	50.2
Contraction	per cent	73	88.4

cracks and fissures. Electrolytic iron in gas turbine blades appears to be quite able to withstand wear and also resistant against surface corrosion and erosion, provided, however, no substantial amounts of wet steam or water are present in the gases of combustion.

NOZZLE SHAPES.

DeLaval nozzles and nozzles with parallel exit walls were tested as well as several other shapes. The advantage of nozzles with parallel walls which lies in their offering a greater cross-section of exit is counterbalanced by an increase in deflection of jet and on the whole it was found that steam turbine experience applies within reason to the design of gas turbine. Most satisfaction was obtained with DeLaval nozzles with minimum possible angle of exit just as in steam turbine practice.

Practical experience has confirmed theoretical expectations to the effect that the reduction of heat fall during the expansion does not materially affect the efficiency of the gas turbine nozzles and blading. For example, if the instantaneous maximum jet velocity at the beginning of expansion is in the neighborhood of 1500 m. per sec., more than 95 per cent of the mechanical energy of the gases of combustion are available at the wheel up to the time when the jet velocity sinks to about 1000 m. per sec. This means that more than 95 per cent of the energy is available at jet velocities varying 19 per cent either way from the average jet velocity for which the nozzle and blading have been designed. Practical experience confirms these theoretical considerations. Time after time useful efficiencies of about 55 per cent (i.e. about 55 per cent of the output attainable in a gas turbine free from all losses) have been indicated in the periphery of the wheel.

In steam turbine practice the upper and lower limits in the heat fall process are determined on one hand by the initial pressure and temperature of the steam, and on the other hand by the vacuum in the condenser. Furthermore, the peripheral velocity of the rotor is also predetermined and all that the designer can do is to rearrange the stages one way or another. In gas turbines the lower limit of the heat fall is predetermined and for practical purposes so are the peripheral velocity and number of stages. On the other hand, however, the designer is free to vary the upper limit of the heat fall and through this the important ratio (jet velocity ÷ peripheral velocity) without materially affecting thereby the thermal efficiency of the turbine.

CHANGE IN NOZZLE VALVES.

The employment of higher charge pressures and the increase in the cross-section of the nozzles required some changes in the design of the nozzle valves which are described in a very general manner.

TESTS.

The tests were carried out in the presence of various railroad officials in December, 1919. Coke-oven gas was used as fuel with the heat content of 3860 k.cal. per cu.m. The tur-

Table 2.

DATA OF TESTS OF HOLZWARTH-THYSSEN GAS TURBINE.

Gas Consumption, reduced to 0 deg. cent., and 760 mm. mercury pressure, cbm. per hour	300	400	550	630
Heat supplies, cal. per hour	1,150,000	1,530,000	2,110,000	2,415,000
Power output at wheel $\eta_{umf.}$ horse-power	70	251	724	984
Heat consumption, k. cal. per h.p.-hour	16,430	6,090	2,915	2,450
Efficiency η_{umf} per cent	3.9	10.4	21.8	26

bine was driving a dynamo delivering current to a water rheostat. The main test lasted four hours and gave the results shown in Table 2.

Figs. 5 and 6 give the amounts of heat delivered to the turbine per hour, and the efficiency η_{umf} refers to the power output η_{umf} delivered by the wheel. The work consumed in compressing the blast air and gas amounted to about 5.7 per

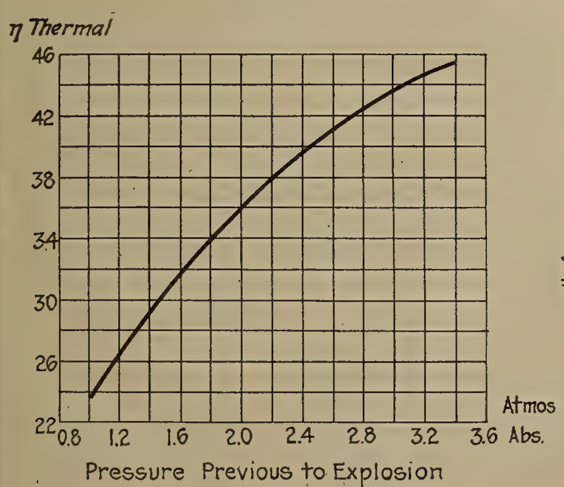


FIG. 4. THERMAL EFFICIENCY OF GAS TURBINE AS A FUNCTION OF CHARGE PRESSURE PREVIOUS TO EXPLOSION (PRODUCER GAS FUEL OF HEAT VALUE 500 CAL. PER CU. M.); TEMPERATURE OF MIXTURE 77 DEG. C.

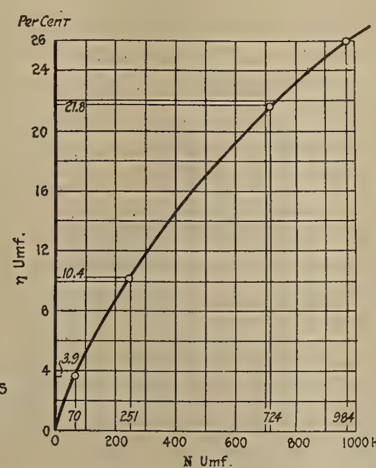


FIG. 5. TOTAL EFFICIENCY (AS MEASURED) ON THE WHEEL PERIPHERY AS A FUNCTION OF THE POWER OUTPUT INDICATED AT THE WHEEL

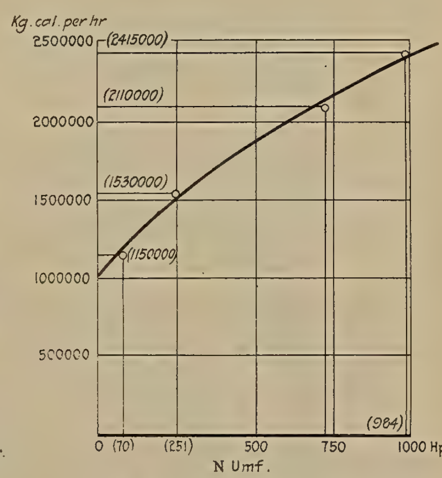


FIG. 6. TOTAL AMOUNT OF HEAT SUPPLIED AS A FUNCTION OF THE POWER OUTPUT AT THE WHEEL OF THE HOLZWARTH OIL FUEL GAS TURBINE

cent of the exhaust heat. If the efficiency of the compressor be assumed to be 70 per cent, of the condenser steam turbine 18 per cent and utilization of exhaust heat 60 per cent, then the total efficiency for the exhaust heat plant and the blower system is 0.70 × 1.19 × 0.16 = 7.6 per cent, in which case the power consumption for the blowers can be well taken care of by exhaust heat.

CONSTRUCTION.

Gas turbines of the horizontal type appear to be preferable in several important ways to vertical turbines, and it is intended in the future to build only horizontal gas turbines. Fig. 3 shows the general oultines of a 500-h.p. oil-fuel gas turbine now under construction to run at 3000 r.p.m. and drive a direct-current generator. The blower and exciter generator are built on the same base as the main engine, and directly connected thereto are the exhaust fuel heated boiler delivering steam for the blowers. This installation is to go to the Prussian Railway Administration. The same article gives an illustration of a 12,000-kw. gas turbine which seems, however, to be only in the design stage as yet.—*Zeitschrift des Vereines Deutsche Ingenieure*, Vol. 54, No. 9, Feb. 28, 1920, pp. 197-201.

Progress in Mining and Metallurgy

Summary of Important Papers

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

THE OIL FIELDS OF RUSSIA.

BY A. BEEBY THOMPSON, London, England.

FOR more than 2500 years, natural gas issues in the Surakhany district of the Apsheron peninsula were the object of pilgrimages by fire worshipers and Hindoos from Burma and India.

Within a few miles of Baku lie the two richest oil fields in the world, viz., the Balakhany-Saboontchy-Romany and the Bibi-Eibat. For many years the gasoline obtained in the refineries of the Baku area was burned in pits, being considered an undesirable product; and until 1870 the residue also was destroyed, its value as a fuel not being recognized. Kerosene was the main product sought by the refiners.

In 1903 the important Grosny oil field was proved by a great flowing well sunk by an enterprising Englishman, who, however, was ruined by the claims for compensation made by peasants whose habitations and lands were destroyed by the deluge of oil, which could not be controlled for years. The property on which the well was drilled has since given over 300,000 bbl. of oil per acre.

In 1901, general interest was directed to the Binagadi oil field by the bringing in of a 10,000-bbl. well.

Another interesting field is Holy Island, off the north coast of the Apsheron peninsula, where 400-bbl. wells have been struck and a considerable area has been proved to be oil-bearing. In 1908, the Surakhany district a few miles southeast of the main Saboontchy oil field was developed by deep wells, and large gushers of the typical Baku oil resulted from beneath the upper light oil and gas-yielding beds that until then had been exclusively worked.

In 1909, the Maikop oil field attracted considerable attention as the result of a large gusher of light oil being struck by almost the first trial well in the Shirvansky district.

A promising oil field was developed, about 1910, in the Emba district north of the Caspian Sea and inland from the port of Gurieff. Around Dossor, large flowing wells were struck, and, prior to the war, extensive arrangements were being made to dispose of the product.

A single Tukestan field, in Fergana on the Trans-Caspian Railway at Chimiono, has yielded substantial supplies of oil that find ready local market.

OIL MANIFESTATIONS AND GEOLOGY.

No country in the world probably exhibits a greater display of oil field surface phenomena than Russia. There are thousands of square miles flanking the Caucasus Mountains and encircling the Caspian Sea that justify an investigation. For miles around the Baku oil fields, the oil series lie spread out like leaves of a book under the nearly desert-like surroundings of that devastated region. Mud volcanoes on a gigantic scale in every stage of activity may be witnessed, as well as perpetual fires fed by incessant issues of natural gas. Acres of asphaltic residues and streams of viscous oils oozing from immense thicknesses of oil-soaked sands are common. These phenomena, mingled with sulfurous waters, present problems for study that are nowhere else reproduced on so large a scale.

Comparatively simple partial domes characterize the two great oil fields of Baku, but both have flanks on one side where the oil-bearing series outcrop and display those surface phenomena usually associated with oil. The whole series of Tertiary strata in which the oil is secreted here consists of unconsolidated clays, sandy clays, and sands of all grades of fineness that readily break down and crumble when pierced by the drill. Their fragile nature is the cause of unusual difficulties in drilling, as throughout a thickness of over 3000 ft. there are constant irregular and ill-defined alterations of sands and clays that merge into one another in a way that makes a log very unreliable when prepared from collected samples. Some sands are charged with oil, some with gas alone, and others with oil and gas. Many of the water-bearing quicksands run freely on penetration and fill the hole to a depth of hundreds of feet. At times, too, oil-saturated clays continue to ooze into the well, which renders progress very difficult.

Certain sandy horizons can occasionally be traced for some distance and definite water and oil horizons have been located within restricted areas. Generally, however, the pliable beds have been so contorted and crushed that no single bed can be recognized for any considerable distance. Geological study was always made more difficult by the further disruption the beds sustained when rich oil sands were struck, masses of surrounding strata were expelled on penetrating a rich oil sand, and this was generally followed by thousands of tons of sand which was either ejected with oil during flows or removed with the oil during the later process of its abstraction. As much as 50 per cent sand (by weight) has been obtained suspended in the oil for a time, and often as much as 10,000 tons of sand have been ejected daily and for weeks from a well piercing a virgin and prolific sand body.

DRILLING OPERATIONS AND YIELDS.

Owing to the highly disturbed and unconsolidated sediments in the Baku oil fields it has been found impossible to adopt there the standard American cable system or even the rotary. The need for wells having exceptionally large initial and completed diameters arises from the necessity to exclude waters and penetrate swelling and caving ground during progress, as well as to permit of the extraction of oil by bailers; consequently, the "stove-pipe" class is mostly employed. Initial diameters of 36 in. to 40 in. (91 to 101 cm.) are usual when

ultimate diameters of 12 in. to 14 in. are desired at a depth of 2000 ft. Massive surface gear is necessary to manipulate columns of such size and the tools required.—Abstract of paper to be read at the St. Louis Meeting of the Amer. Inst. of Min. & Met. Eng.

PULVERIZED COAL AT HIGH ALTITUDES.

By Otis L. McIntyre.

The Cerro de Paslo Copper Corporation, at La Fundicion, Peru, used about 65,000 tons of coke per year, of which about 85 per cent is local coke made at the smelter, and 15 per cent is imported. This latter is very expensive, and as both classes of coke enter largely into the smelting costs, it was decided to experiment with pulverized coal in the various departments of the smelter. The preliminary work consisted in determining the general combustibility of the local coals in pulverized form. The coal was dried by hand on steam hot pans to less than 1 per cent moisture, and then ground in a 4 in. by 4 in. Marcy mill.

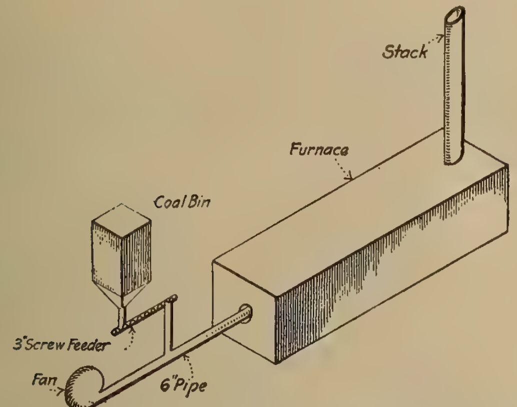


FIG. 1. FIRST LAYOUT OF EQUIPMENT USED IN TEST

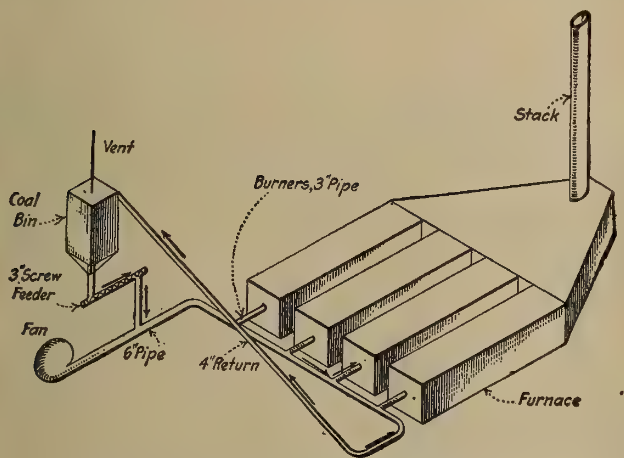


FIG. 2. SECOND LAYOUT OF EQUIPMENT FOR FURNACE TESTS OF PULVERIZED COAL

The equipment used in the test is shown in Fig. 1. It consists of coal hopper, a 3-in. feed screw driven by variable-speed motor, and a No. 2 Sturtevant blower supplying the air. The burner was a standard 6-in. pipe projecting about 12 in. into the furnace, which was approximately 4 by 4 by 16 ft. and constructed of fire-brick. No pyrometric measurements were taken, but observation of the furnace showed the results to be satisfactory.

The tests were first made with pure pulverized coal, and then with mixtures of coal and coke breeze, varying from 10 to 35 per cent of coke breeze, which gave practically the same results as the pure coal. The layout was then changed, as shown in Fig 2, to test the practicability of using more than one burner with a single feeder. This test was run with the 4-in. return pipe both open and closed, the results indicating that satisfactory operation could be obtained by either method with a properly proportioned pipe system.

The next test was to sinter the fine ores on a standard Dwight-Lloyd sintering machine. These machines are oil-fired, and if coal could be substituted a considerable saving would be effected. The equipment used in this test was the same as is shown in Fig. 1, except that a 1-in. screw feeder, a smaller fan, and a 2-in. pipe burner were used. This test produced a satisfactory sinter, though some trouble was encountered in the primary ignition of the coal, and the standard oil muffle was too small.

The next experiment was to test the feasibility of conveying pulverized coal under direct air pressure; the layout used is shown in Fig. 3. Pulverized coal was placed in the pressure tank and air at 20 to 25 lb. was admitted through the ¾-in. pipe at the top of the tank. The 4-in. valve at the bottom was then opened and the coal passed through the 4-in. piping system to the coal hopper. In this way 4000 lb. of coal was transported in 1½ to 2 min. The loss through the vent pipe varied from 100 to 200 lb. This can be remedied by using dust collectors on the hopper, or an exhaust system which would return this waste coal to the main hopper.

The foregoing tests showing up so well, it was decided to erect a larger experimental pulverizing plant.

The furnace performance through all tests was found to be fully equal to that when operating on the normal coke charge. Two difficulties were encountered, namely, keeping some of the feeders in operation and keeping the tuyeres open. In some of the feeders there was a slight back pressure, due probably to partly blocked tuyeres. This did not affect materially the feeding, but forced some coal dust into the feeder bearings, which mixed with the oil and finally bound the bearings. By using dust-proof bearings and a better-designed injector, we expect to eliminate this trouble.

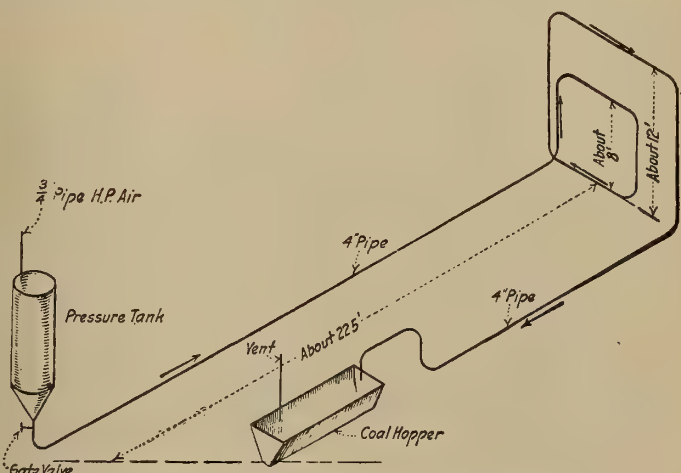


FIG. 3. TEST OF FEASIBILITY OF CONVEYING PULVERIZED COAL UNDER DIRECT AIR PRESSURE

Keeping the tuyers open is absolutely essential to the safe and efficient operation of this process. In view of the difficulty of keeping the tuyeres open and the connections airtight, it is probable that the most satisfactory place to inject the coal into the furnace would be through a separate opening in the jackets, between and somewhat above the tuyeres.

The No. 5 reverberatory was selected for the final test. This test was disappointing from the actual results, but when the following difficulties which were encountered are corrected, the furnace will, beyond question, show a much higher efficiency than the hand-fired furnace. First, the coal could not be dried sufficiently, the average moisture being in excess of 1.5 per cent. The plant would not grind sufficient coal to the required fineness. The discharge from hopper to feeder

was too small, and the coal continually caked and bridged. The screw feeder was too short so that the coal flushed badly at times; also the discharge from the feeder was too far from the fan so that the coal accumulated in the suction pipe and had to be removed with an air jet.

This test covered about nine days, and was run for about two days with the return pipe open. Some time during the second day the return pipe was blocked, due to overfeeding, so it was decided to continue the test without opening the run pipe; the only difference was an apparently heavier feed at the burner farthest from the fan. With a properly designed piping system there seems to be no reason why a series of burners cannot be operated from a single feeder with or without a return. The last day's run of this test was made with a mixture of 75 per cent coal and 25 per cent coke breeze, which gave results equal to straight coal. It may be of interest to note that these experiments and tests were carried out at an elevation of 14,200 ft.—Abstracted from paper to be presented before the American Society of Mechanical Engineers in St. Louis, May 24 to 27, 1920.

OUTLINE FOR ANALYSIS OF OIL-FIELD WATER PROBLEMS.

By A. W. Ambrose, Bartlesville, Okla.

The underground losses of oil exceed, by hundreds of thousands of barrels, all the oil that has been lost in storage, transportation, or refining. The quantity lost is, of course, indeterminate; but when it is considered that the contents of an entire oil field have been excluded from recovery by invading waters, some idea of the amount wasted may be gained. Similarly, enormous quantities of gas have been lost under ground. Conservation of the oil, therefore, should start before it is brought to the surface rather than after it is placed in storage tanks.

In an area drilled with a hole full of mud or fluid the operator should consider the contents of a sand which has been as an unknown quantity, unless the sand tested in a neighboring well by bailing or pumping. In an area where the hole is filled with water while drilling, the hydrostatic head of fluid in the hole is usually greater than that of the water or oil in the sand, hence oil or water will not come from the sand into the drilling well. Fig. 4 is a hypothetical sketch showing several possible waters in a producing oil field.

Those waters A and A_1 occurring in the sand above the producing oil horizon are generally known as top, or upper, waters. Top water may have access to the hole by: The shut-off being too high; the water leaking around the shoe of the water string; poor coupling connections, due to cross-threading or the pipe not being screwed tight; collapsed casing; a split in the casing, pipe worn through by drilling-line wear, or corrosion of the casing due to strong corrosive waters in the sands.

Bottom waters E are those occurring in sand below the producing oil horizons. To avoid bottom water, it is necessary to learn the exact distance between the top of the water sand and the base of the oil zone, so that the operator can avoid drilling too deeply.

Where there are several producing oil or gas horizons, the water C occurring between the producing sands is generally referred to as intermediate water. (If there are only two producing sands, the term middle water is often applied to the water occurring in a sand between them.)

Edge water D occurs in the down-slope portion of an oil or gas stratum. Edge water may be middle water in one well and bottom water in another part of the field. It usually encroaches as production is drawn from the wells up slope. The sand is termed an oil producer up slope, but wells drilled into the same sand down slope will produce water.

Water may occur in the base of an oil sand, although before drawing such conclusions it is advisable to consider carefully whether or not there is a small formational break of an impervious bed between the oil and water. Water, also, may occur in a lenticular body of sand and should be treated as top, bottom, or intermediate water, according to its location with respect to the productive sands.

The flooding of the oil sands of an area by top, bottom, or intermediate water can often be prevented by the correction of a few offending wells when the trouble starts. The operator should, therefore, investigate promptly any marked increase in the water content of a well.

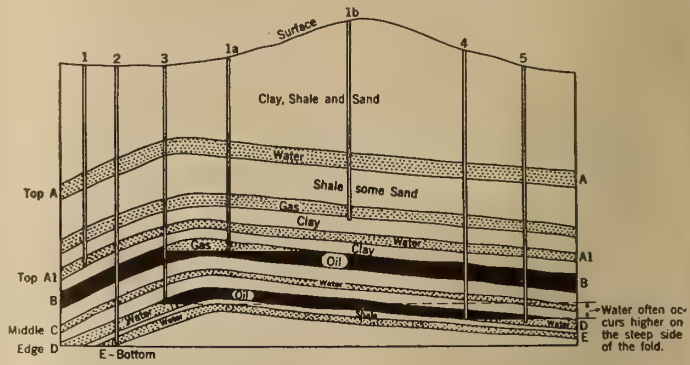


FIG. 4. HYPOTHETICAL SKETCH SHOWING DIFFERENT WATER SANDS

The indications of a field going to water vary with each locality, but the most common and positive evidence is for the oil wells to start producing water. When a group of wells located high up on the structure, for instance on the top of a dome, show water while wells down slope do not, some well is at fault. In such a case the cause may be due to improper water shut-off points, leaky water strings, wells drilled into bottom water, or wells improperly plugged when abandoned. Top water, bottom water, and water in a lenticular sand usually lend themselves to repair work on the wells.

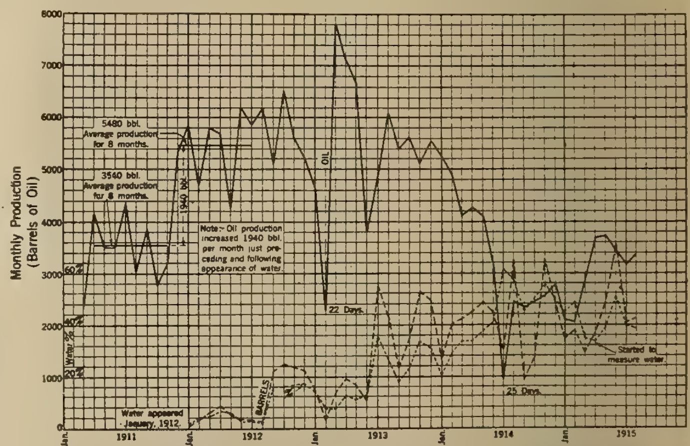


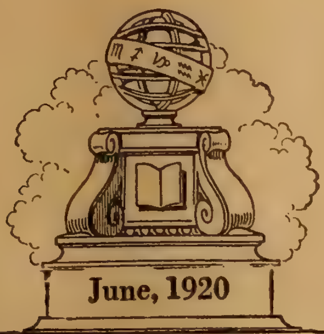
FIG. 5. INCREASE IN PRODUCTION OF OIL WELL PRIOR TO ENCROACHMENT OF EDGE WATER

Water in the base of an oil sand and edge water presents a much more serious problem, for as the oil and gas are withdrawn they will be replaced by water. Water in the base of an oil sand often occurs in abundant quantities; if a hole is carefully plugged up with cement the water production is only temporarily retarded. When the wells farthest down slope, located along a line parallel in general to the underground contours, show an increased water content, there is suspicion of the encroachment of edge water.

A sudden increase in oil production has been noticed in wells just before edge water appears. This is shown in Fig. 5. It will be noticed that the average production per month was 1940 bbl. more following the appearance of water in appreciable quantities in January, 1912.—Abstract of paper to be read at the St. Louis Meeting of Amer. Inst. of Min. & Met. Eng.

SCIENTIFIC AMERICAN MONTHLY

FORMERLY SCIENTIFIC AMERICAN SUPPLEMENT



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INSECT FOES OF BOOKS—SEARCHING FOR XYLOPHAGOUS OR WOOD-EATING INSECTS. THESE EXHIBIT AN "ACQUIRED" TASTE FOR BOOKS (SEE PAGE 496)

SCIENTIFIC AMERICAN MONTHLY

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MODERN VIEWS ON DEVELOPMENT OF CHILDREN.

JUST as children in former ages of the world were dressed like their parents so that they presented small replicas of the former, so it was supposed that they resembled them in body and mind except so far as the matter of size was concerned. Modern investigations, however, have proved quite definitely that there are very marked differences between children and their elders, both in brain and in body and in those organs of the senses by means of which physiological impressions become psychological sensations. It is worth while, therefore at this season of commencements to consider these things in relation to schools.

We are indebted to an article appearing in the Supplement of the *Chemiker-Zeitung* (Berlin) for some interesting data on recent researches in this field.

It is not generally known that the composition of the chemical elements required by the child's body is very different from that required by older persons and the younger the child the greater this difference is. Thus, a new-born infant's body contains 74.7 per cent of water while an adult's contains only 58.5 per cent. Again the bones of the former are softer because they contain less mineral substance.

In the course of the child's development the heart becomes 12 to 13 times as large as at first, the liver eleven times, the lungs nearly 20 times, and the brain 4 times as large.

Quite as striking is the change in the comparative percentage of the mineral salts in the body of a growing child. In the case of the cartilage, for example, the proportion is 2.24 per cent at 6 months of age, 3.00 per cent at 3 years, and 7.29 per cent at the age of 19. These figures make it sufficiently obvious why ease and grace of movement should be attained by dancing, climbing, running and other physical exercises in early youth, and why on the other hand the greatest care should be taken to prevent the strains attendant upon heavy lifting and the possibilities of curvature of the spine and other deformities consequent upon a too long continuance in a given position or action. These considerations are enough to emphasize the danger of factory work for children.

Even in the composition of the blood there is a marked difference—that of the child containing such a large percentage of white blood corpuscles, or leucocytes, that should the blood of an adult contain the same proportion he would be regarded as seriously anæmic.

But in nothing is the difference between youth and maturity more marked than in the manifold alterations which occur in the bones of the skull during adolescence, and clearly this is a matter of prime importance with regard to a wise plan of education. Not only is the size of the skull in relation to the height of the invidual different in the child, but there is a difference as concerns the relation between the height and breadth of the skull itself. In a new-born infant the skull is comparatively large, its length being one-fourth that of the entire height. At 2 years of age this proportion has decreased to 1/5, at six to 1/6, at 15 to 1/7, and at 25 to ⅛. Again the skull is at least as broad as it is long in the new-born child at its point of greatest width whereas in the adult the breadth equals only ¾ of the length. The size and form of the separate bones of the skull vary considerably at different ages during childhood and in consequence of this the relative position of the features undergoes variation. Thus at birth the nostrils are placed only a short distance below the socket of the eye, but as the infant develops this distance gradually increases.

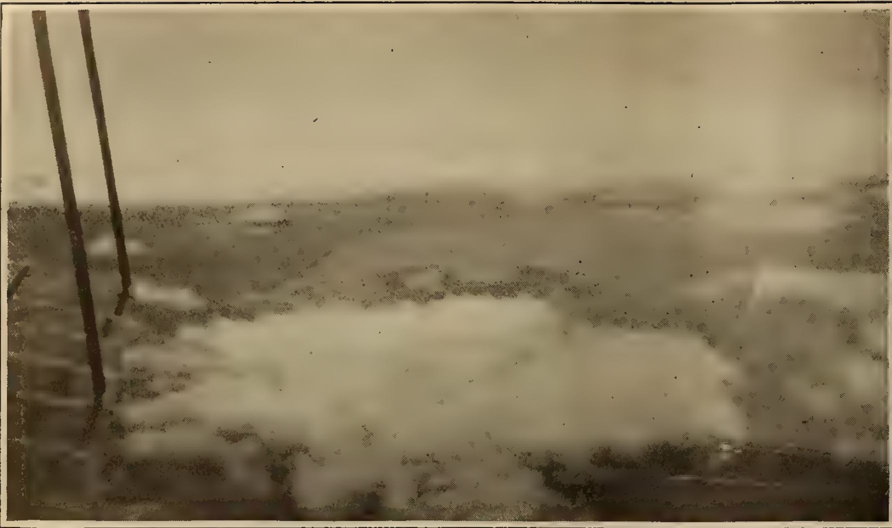
When first born the infant is practically blind and deaf. In the infant the Eustachian tube lies in a nearly horizontal position, while it bends abruptly downward in the adult. For this reason inflammation of the nasal passages and the throat much more readily affect the middle ear in the child. There are marked differences, too, in the formation of the tongue and of the larynx, and naturally these are closely concerned with the development of the powers of speech.

Peculiarly remarkable in children is the large size of the thymus gland, which is almost as large at birth as the left side of the lungs. This gland continues to increase in size till about the third year, remains practically stationary till the beginning of puberty and then disappears. It apparently exerts a definite influence upon the metabolism of early childhood.

We cannot here go into all the variations which occur in the vital organs during growth, but it is worth while mentioning that during childhood the heart is comparatively small with respect to the height of the body, while the arterial system is highly developed. When puberty arrives these proportions are gradually reversed. As a result of these conditions the blood pressure of a child is lower than that of an adult, except in the lungs, where it is higher because the lung artery in a child has a greater diameter than the main artery. This causes a more rapid breathing and a greater liberation of CO_2. This explains the greater activity of the child and the cruelty and folly of requiring it to maintain the same position for hours at a time.

Particular attention is due, too, to the differences in the spine, which is broader and shorter in the child than in the adult. It is extremely soft and flexible, too, hence the danger of curvature, which is sometimes induced merely by carrying a heavy load of books always on one side.

Enough has been said, we believe, to show that the faculty of every school, whether public or private, should include at least one member who has a definite knowledge of juvenile anatomy at every period of growth.



SAN DIEGO BAY PHOTOGRAPHED FROM AN ELEVATION OF 3,000 FEET ABOVE POINT LOMA

CRESTS OF CIRRO-CUMULUS CLOUDS FROM AN ELEVATION OF 6,550 FEET

Photographing Clouds from an Airplane*

Journey Through "The Landscape of the Sky"

By Ford A. Carpenter

Manager of the Department of Meteorology and Aeronautics of the Los Angeles Chamber of Commerce

BEING out of kodak films the writer dropped down from a ten-thousand-foot altitude, requisitioned a Ford from the transport officer at Rockwell field and crossed the causeway to Coronado. Sauntering into the cool and spacious lobby of the Hotel del Coronado he asked the clerk the way to the photograph department. The clerk recognized him as the former Weather Man at San Diego and greeted him heartily. "Won't you stay and have dinner with us?" "No," I replied, "I promised Frank Miller, Master of the Inn at Riverside, when I lunched there this afternoon, to dine with him on my return this evening." As I turned to buy the kodak films one of the flannel-clad, bored-looking individuals who had heard the conversation detained me with "Beg your pardon, but did I hear correctly? That you had lunched this afternoon at Riverside, and expect to dine there at six o'clock tonight?" "Sure," I replied, "I left the Mission Inn shortly after one o'clock, motored to March field, took a JN-4 and having used up the last of my kodak films dropped down here to get some more." "No, I am not an aviator—just a plain, ordinary citizen out on a cloud photographing trip." The flannel-clad individual flipped the ash from his cigarette, turned to his interested companion and ejaculated: "Here's where my ten-thousand-dollar Rolls-Royce goes into the discard."

To my mind this incident illustrates the early superseding of the automobile by the airplane by people who want to accomplish a journey quickly and comfortably. All air-lanes are direct and smooth, although in rare cases perhaps a trifle billowy. While the aviator should be competent to "stunt" in an emergency it should be no more the rule to practice acrobatics in the air than for the ordinary touring car to emulate a daredevil auto racer.

The three-hundred mile cross-country flight of last July was made for the purpose of photographing the higher variety of summer clouds and studying them at close range. Incidentally it was to extend further our studies into differing air levels, continuing this work begun in June. Most of my investigation into air levels of southern California has been accomplished by means of free balloons during a dozen or more flights during all hours of the day and night.

*Abstracted from *The Ace*, Jan., 1920.

Recognizing the importance of aerial mapping and cloud studies from aloft, the Director of Air Service kindly placed a two-seater and an experienced pilot, Lieut. H. E. Queen, at my disposal for the afternoon. I decided to make the triangular course from Riverside to San Diego and along the coast from San Diego to Los Angeles and thence to the place of starting. The accompanying photographs with their notes were all made by the writer while in the air. Following out a custom inaugurated early in 1911, when air work was first begun by him, a five-minute log was kept. The importance of making one's notes and sketches at regular intervals *at the time* cannot be too highly recommended. I believe that most of the errors of observation are those which creep into notes made afterwards, and, doubtless, are unintentionally colored by the imagination.

NOTE BOOK ENTRIES.

Note book of airplane flight of July 17, 1919, shows the following summary:

March Field to San Diego and return via Los Angeles:

Flight		Mins.	Miles
	Ar DeMille Field 5:27 P. M.		
	Ar Rockwell Field 2:21 P. M.	76	90
No. 2	Lv Rockwell Field 3:39 P. M.		
	Ar DeMille Field 5:27 P. M.	108	130
No. 3	Lv Rockwell Field 6:02 P. M.		
	Ar March Field 6:57 P. M.	55	60
Totals		239	280

OBSERVATION OF CLOUDS.

To the aviator, clouds are a sure guide to the weather in the different air levels, and too much emphasis cannot be laid upon the importance of a thorough knowledge of cloud structure, cloud movement and the resulting weather conditions. To my mind cloud study should comprise as much as one-half of a course in meteorology.

Previous to the last few hundred years weather forecasting with the least pretense to a scientific basis was founded on no other observations than the character and movement of clouds. And now, at the present stage of the knowledge of meteorology, they still give the most valuable local indication

LANDING THROUGH VELO CLOUDS ON THE ROCKWELL FIELD

MOUNT SOLEDAD (LA JOLLA) PARTLY COVERED WITH VELO CLOUD

of coming changes in weather conditions. The clouds, by their character, indicate the observer's position and proximity with reference to the low pressure area.

A moment's reflection shows that the true direction, as well as the force of the drift of the earth's atmosphere, as depicted by the clouds, is conclusive as a weather indication only in that it determines the relative position and intensity of the storm center.

"WEATHER" IS UNDER 20,000 FEET.

The layer of cloud covering the earth is relatively very thin. If, for example, we could examine the earth from the moon, we would doubtless see a veil of cloud covering little more than half the surface. At that distance the clouds would have no texture, the earth would appear swathed in an irregular sheet of formless vapor, through which, from time to time, the land and water areas could be seen.

The cloud-cover of the earth is most attenuated; it may be compared to a film, for it is supposed to be less than one eight-hundredth of the earth's diameter in vertical thickness.

The thinness of the earth's atmosphere may be more clearly comprehended if we realiize that the relative thickness of the cloud-layer on an eight-inch terrestrial globe would be about one-hundredth of an inch. Yet it is in this thin belt that clouds form, so that it is seen our weather is produced within limited confines.

It is not often given one to select a day when most varieties of clouds are in evidence. First I thought that there would be insufficient clouds on the day selected, and later, from the threatening aspect of the cumulo-nimbus clouds over the mountains and in the high levels, it seemed as if there might be too many varieties of the sterner sort. Fortune again favored me and we had on this journey practically all of the varieties.

COMPOSITION OF CLOUDS.

Clouds occur whenever the temperature is lower than the saturation-point of the air, so that no matter how light or fleecy they may be, or how dense may be the fog, the cloud-mass shows by its presence that precipitation is taking place. Their height defines their relative density.

Here are the general classifications: Cirrus, cumulus, stratus and nimbus.

Cirrus, the Highest Cloud.—This is of delicate fiber, feathery in structure and pure white in color. It is the most elevated of all clouds, having an average altitude of five miles, and sometimes extending into the lower limit of the so-called isothermal region of the atmosphere. This cloud is doubtless composed of spiculae of ice. A popular name for this cloud is "mare's tails," and it is the wind cloud of the sailors.

Cumulus, the Day Cloud.—The typical summer clouds that thrust their heads up into the air—they are the great conventional clouds. Generally speaking they are thick and dense and their tops are smaller than their bases. As they are caused by ascending currents, their life is dependent upon the duration of the vertical current, so that when the air ceases to rise, the cloud disappears. During the ascent of the sounding balloons at Avalon, Catalina Island, in the summer of 1913, especial care had to be taken not to let loose the balloons during the proximity of cumulus clouds, as they were the danger signals of strong upward air currents.

Stratus, the Lower Cloud, is a gray, undefined cloud sheet; in fact, any horizontal mass of uniform thickness, independent of height, characterizes this cloud. When it is of low altitude it sometimes becomes the velo cloud. The stratus cloud is of considerable value as an insulator of the sun's rays, and, on the other hand, almost entirely checks the loss of heat by radiation from the earth at night. May and June would be among the hot months in littoral California were it not for the cloud then prevailing. In winter, citrus growers know that there will be no frost if stratus clouds are present, for they serve as a blanket and thus hold the earth's heat.

Nimbus, the Rain Cloud, is, technically, any cloud mass from which precipitation is falling. It always forms under a higher variety of cloud.

MODIFICATION OF CLOUD FORMS.

These four are the general classification of clouds all over the world. A modification of these varieties gives the following modifications:

Cirro-Stratus, which is easily distinguished by the fact that in it are formed the halos. The diffraction of light by this cloud produces rings around the sun and moon, technically known as the solar and lunar halos of 22° and 45° radii.

Cirro-Cumulus forms in semi-transparent balls; it is the mackerel sky cloud that forms suddenly and marks the transitory stage between a higher and a lower variety, or *vice versa*. This cloud was very much in evidence within a quarter of an hour after leaving March Field. It was like sailing from one aerial haystack to another, so well-defined were these round cloudy masses. When this cloud is accompanied by threatening phenomena it is the surest rain indication that we have in southern California.

Alto-Cumulus is composed of small masses of cumulus cloud in parallel rows.

Fracto-Cumulus.—This term is applied to a cumulus cloud when its edges are torn or shredded by the wind.

Alto-Stratus is a high stratus cloud, nearly always thickening into the ordinary low type and becomes a somewhat threatening cloud. This formation causes solar and lunar coronae.

Strato-Cumulus.—Long feathery rolls, which are shallow in winter, and if present in quantities, are a threatening indication. During the spring and summer, they generally disappear without causing precipitation.

Fracto-Stratus is the lowest cloud form, and is therefore only a slight remove from fog tattered by the surface wind.

Cumulo-Nimbus is the "thunderhead," and the most impressive of all cloud forms. When whisps of thundercloud are seen above the towering masses they are called "false cirrus."

Fracto-Nimbus.—Near the level of the sea this is the "scud" of the sailors. Among the higher levels, it sometimes occurs as a trail of cloud dark with moisture stringing after the larger cloud, sometimes dissipating before the lower edges of the veil reach the earth.

The study of the composition of the clouds is quite important if we wish to interpret their meteorological significance correctly. The altering composition of a cloud-mass, whether a higher cloud is changing to a lower variety, or whether a cloud near the earth is dissipating—both processes having a direct bearing on local weather conditions.

FORMATION OF CLOUDS.

Before leaving this subject let us examine into the causes which underlie the structure of cloud.

Minute nuclei make possible formation. Laboratory experiments demonstrate that condensation in air cannot occur unless there is some object on which the condensation can take place, whether it be a material surface, a dust or water particle.

Nuclei are necessary for the formation of a water drop. It is a most important fact that a water drop cannot be formed in the free air unless there first be a nucleus on which the moisture can be deposited. The nuclei may be dust particles or ions. Experiments show that the condensation occurs at a much lower temperature in dust-free air, so that dust particles are by far the more important source of nuclei. As for dust, it must not be supposed that condensation is delayed on account of the absence of dust nuclei, for we have no instance in nature where the air is so pure near the earth that vapor could not form. A beam of light, whether it be from the sun or an artificial source, shows innumerable dust motes in its projection through the air. In fact, we know that light itself is made visible because of the presence of these dust motes. The dustier the air, the greater the diffusion of light. As ionized air permits condensation though dust may be absent, it is probable that the condensation at the higher levels of the atmosphere may be thus caused.

THE SIZE OF A DROP OF WATER.

The size of water drops has been found to average one-thousandth of an inch in diameter. Experiments prove that such a drop falls at the rate of two inches per second. This unusually slow rate led the earlier investigators to believe that droplets were hollow spheres, hence the vesicular theory of rain formation. It has since been discovered that particles of steam or fog are solid globes. Ascending air currents readily suspend such minute and slowly falling particles, often forcing them upward a great distance. In the case of thunder storms, the convectional force is terrific; witness the size of hailstones which owe their size to their being forced upward many times to a great height for their numerous coatings of ice.

Condensation necessary for the formation of clouds may be caused by either convection or contact. Convectional clouds are produced not because the air mass rises into a colder region, but because the mass itself has been dynamically cooled. Cumulus clouds, rain clouds, and rain itself, are due to dynamic cooling.

Another form of convection results from the great whirling eddies of the atmosphere, which are the "lows" of the weather map. Local reduction in atmospheric pressure will also cause ascending currents.

DOWN CURRENTS GIVE FAIR WEATHER, UP CURRENTS RAIN.

Whether or not the currents are ascending or descending may be readily observed by the tips or tufts of the cloud formation. If these feather edges point downward, we know that the winds are descending and therefore becoming warm and dry; if ascending they are becoming cool and moisture-laden. Local ascending currents may be caused by forest or other fires. Spectators of the great San Francisco fire described a towering cumulus cloud which overhung the burning city. When a fierce forest fire occurs on a calm day a small cumulus cloud capping the smoke column is not an unusual sight.

MEASUREMENTS UP TO 108,000 FEET OF ALTITUDE.

In the summer of 1913 cloud investigations were carried on by the aid of free balloons. For example, the balloon soundings at Avalon in July and August of that year revealed some of the innermost secrets of the clouds. The records from the instruments, which soared twenty miles and over, showed that the steady decrease in moisture is uniform, becoming practically nil at the upper limits.

It was also found that the "velo cloud" (a cloud peculiar to the Pacific coast, which will be described later) extends upwards on an average of one-quarter of a mile; that the trade-wind is about two and one-half miles thick; and that the particles composing the highest cirrus clouds are widely separated and are continually forming and re-forming, generally at an elevation exceeding five miles.

THE LIONS OF THE SKY.

The first clouds encountered on this journey were the cumulo-nimbus. In the air it is sometimes difficult to determine whether a towering thunderhead is a cloud or a mist-covered mountain.

At first sight it was somewhat terrifying, for the plane was apparently headed for destruction. But like Bunyan's lions their appearance only was terrifying.

It was observed especially whether the eddying wind movement in the vicinity of these clouds affected the behavior of the ship. It did not. Perhaps it was owing to the skill of the navigator, much as a good sailor will so take advantage of wind and currents as to keep his vessel from either pitching or rolling.

THE SHEEP OF THE SKY.

If the thunderheads are the lions of the sky, then the cirro-cumulus are the peaceful sheep. In regard to the cirro-cumulus my notes say:

"No sight is more exquisite than the cirro-cumulus cloud-flecked air as seen from above."

As these cirro-cumulus clouds became more closely packed it was like sailing from one hill-top of mist to another. We passed through several; some were dense enough to obscure the light, and this part of the journey was like traveling through a very short and quite dark tunnel.

The minutes sped by so rapidly that before I realized it the long low-lying cloud which had been observed skirting the coast resolved itself into our old familiar friend the velo cloud.

THE VELO CLOUD.

This cloud is peculiarly a product of the Pacific coast; of all the delightful memories of San Diego the one that sticks closest is that of this early morning and late evening cloud. The writer described this cloud in a small volume on local climatology[1] from which the following has been condensed:

"EL VELO DE LA LUZ."

The challenge, "We all know the winters are warm in San Diego, therefore the summers must be hot," constitutes the most common misunderstanding of San Diego's cool summers. The fact that there is less than one hour per year above 90

[1] Climate and Weather of San Diego, by Ford A. Carpenter, Mount Pleasant Press, 1913.

CIRRO-STRATUS CLOUDS IN WHICH SOLAR HALOS ARE FORMED

LOOKING DOWN ON A CIRRO-CUMULUS CLOUD

CUMULO-NIMBUS CLOUDS COMMONLY KNOWN AS "THUNDERHEADS"

degrees is not easy to explain, until we remember the old Mexican phrase, El velo de la luz, "The veil that hides the light." This is a folklore expression, originating not only before the Gringo came, but, doubtless, long before the coming of the old Spanish conquistadors. The better-known English term, "high fog," has, in common with most words of our language, a double meaning, and it is misleading to a non-resident.

It is not fog in the generally accepted meaning, for this "light veil" is neither cold nor excessively moisture-laden. Neither is it high, for its altitude is less than a thousand feet.

While the velo cloud is common to the Pacific coast generally, and has been observed as far north as the Straits of Fuca, this cloud reached its perfection over the littoral region of southern California.

The velo cloud is the chief characteristic of the summer climate of the San Diego Bay region. And summer should be understood as covering all the year excepting November, December, January and February. These four months could easily be reckoned as spring-time.

The screening of this region from the sun's rays is so thoroughly accomplished that, during a normal summer's day, the sun breaks through the velo cloud about 10 o'clock, the sky clearing shortly afterwards and remaining free from clouds until about sunset.

That the velo cloud is effective as a sun-shield, it needs only to be stated that the average of all the July maximum weather temperatures since weather observations began shows a mean of about 78 degrees.

The cause of the formation of the celo cloud and, consequently, the cool summers of San Diego is, strange to say, found in the hot weather in the interior of California and Arizona. It is a unique example of the aptness of the proverb, "It's an ill wind that blows nobody good."

The hot weather in the interior produces an aerial eddy (the "low" of the weather map), and the difference in atmospheric pressure between the interior and the ocean results in giving San Diego cool, uniform days and nights, free from extremes, or what is really the summer temperature of the Pacific ocean. The velo cloud should therefore be incorporated in our local vocabulary, and it should replace the misnomer "high fog."

LAKES AS SEEN FROM THE AIR.

One of the most exquisite views from a plane, in my opinion, is a lake or reservoir, and Lake Hodges on the San Dieguito River, which we passed over at nearly eight thousand feet elevation, was no exception to the rule.

Owing to the time of the year the water in this artificial lake was somewhat depleted, leaving a shimmering, white border which formed the edge of the lake.

As Lake Hodges was not on the map it was quite disconcerting to locate our whereabouts, but with the compass I decided that the lake had been created since the map was printed.

This is another example of the usefulness of the airplane in not only showing very clearly the necessity for accurate maps, but filling that want with the aid of a camera.

COLORING FROM THE AIR.

I never cease to marvel, when in either an airplane or in a balloon, at the colors which spread out beneath one. This was especially true in negotiating the air over the beautiful grounds of the thousand-acre park, not long since the scene of the Panama-Pacific Exposition. Owing to the vertical vision there are advantages about airplane and balloon observation totally lacking in any other view.

Someone has compared such a scene to an exquisite Persian rug spread out beneath him. Be that as it may, every field,

every kind of crop, the varying geological formations all stand out with startling clearness. Viewed from above, low trees, brush and other chaparral have a texture of almost inviting downiness. I have often thought that a good colorist could make his fortune if he would paint from a balloon basket or the cockpit of an airplane.

As in all art there is no gain without some loss. Although the colors stand out with great vividness the majesty of the mountains and the beauty of the canyons and the running streams is lost. In my opinion there is still but one way to enjoy nature and that is on foot or on horseback. The airplane is no improvement over the automobile for the enjoyment of scenery.

From Point Loma on until we swung inland near Point Firmin the trip was that of a seaplane. For nearly one hundred miles the plane thundered its way on an even keel four thousand feet above the shimmering sea. Whenever the ship swung towards the shore, even ever so slightly, the differing paths could be readily determined by the contrasting shades. As color values were entrancing when flying over the fields, so also was the sight when skimming the meadows of the sea with its acres and acres of exquisitely colored seaweed. This was especially in evidence as we winged our way over La Jolla with its turquoise bay and paralleled opalescent cliffs of Del Mar. The hum of the motor and the singing of the struts and stays in the hurrying air, together with the even temperature so near the ocean, produced a drowsiness and only the imperative duty of making five-minute notes kept me awake.

A PHYSIOLOGICAL SELF-EXAMINATION.

Seated comfortably and calmly in the protected cockpit I took advantage of the opportunity for a careful self-examination as to the effect of flying on the human system so far as I was personally concerned. I reviewed the pulse tests which I had made at differing elevations; at 10,000 feet or at 2,000 there was not the difference of half a dozen beats. The bodily temperature remained the same at different altitudes. In the sudden drop from 10,000 feet to sea-level at Rockwell Field I noticed pains in the ears which lasted several minutes after landing. There was not at any time the least sensation of dizziness, although being rapidly subject to seasickness or carsickness. I had long wanted to try out whether or not I could hear myself shout in a plane. Removing the helmet I yelled at the top of my voice, but such was the drone of the motor and the hurricane blast of air that even the head-noise could not be distinguished.

WIND EFFECT OF DEBOUCHING CANYONS.

Most pilots state that with a fast plane there is no appreciable effect on traveling past the mouth of canyons debouching into the sea. In order to prove or disprove this the following observations were made. As is well known, the seacoast from Point Loma to Point Firmin is furrowed by deep canyons emptying into the ocean. The speed of the plane was too rapid to permit a view of approaching canyons, so for several minutes at a time I closed my eyes in order that sight might not confuse a preconceived notion, only opening them when the ship lurched. Five observations thus made of slight sideslips were directly traceable to the passing of canyon mouths.

PHOTOGRAPHIC EQUIPMENT.

Perhaps a word as to the photographic equipment used in this journey may not be out of place.

It has long been my feeling that it was the man behind the gun rather than the gun that brought down the game—but that goes without saying. At any rate I think that a man should take with him a camera which he is perfectly familiar with. My own practice is to use a common kodak fitted with a fine astigmat lens and a reliable shutter. A universal direct view finder is essential as are also two kinds of rayfilters. On my first journey, many years ago, I was foolish enough to take a foreground filter! Little did I then realize that there is no foreground in the air! Also, there is no need for focusing. It is necessary to set the scale at 100 feet and the shutter and diaphragm at appropriate values and use the camera as man would a machine-gun.

One precaution is necessary in the air: the film must be rolled up with great deliberation, for quick turning of the spool will cause static in the dry air of these elevations with consequent hair lines and blotches on the film. The film must be handled with extreme care both before and after taking the picture.

INSTRUMENTS USED ON THE TRIP.

Before bringing this narrative to a close it might be worth while to mention some of the instruments used independently of the regulation altimeter, compass, etc. I refer to the photographic and meteorological apparatus.

BAROGRAPH RECORD OF JOURNEY.

Two barographs were taken on this journey, one recording on an open scale up to five thousand feet and the other over a more constricted profile up to fifteen thousand feet. Both instruments gave highly comparable and therefore satisfactory results. Naturally the needle passed off the limits of the sheet on the first instrument, but all of the journey was recorded on the second barograph with five thousand feet to spare.

I found these barographs of very great utility in all journeys whether on foot, horseback, automobile, railroad, balloon or airplane. In fact on all means of travel save by steamboat, these barographs give an automatic record of every moment of the journey.

THE HOMEWARD FLIGHT.

After traversing more than half a hundred miles of air fragrant with orange blossoms we flew over Riverside and dropped into the home field. A few minutes after landing I was on a motorcycle and shortly afterwards passed through the hospitable arches of the Mission Inn. Here was where I had lunched only a few hours before and now the cool and quiet interior and warm and friendly greeting of the Master of the Inn added the finishing touches of anticipation of the waiting dinner.

And thus this air trip was ended ninety miles over the mountains, one hundred and thirty along the sea coast and sixty over the orange and lemon groves. Into these four hours of flying were crowded studies of air currents; photographing of clouds at close range; testing out of some intuitional theories and the intimate observation of land, sea and sky. So much was thus made possible in so little time that to my mind this journey brings out with startling distinctness the one great outstanding fact in flying—the expansion of time. In obeying the scriptural injunction "shall mount up with wings as eagles" the airman takes hold upon divinity for can he not also say with scripture "One day is with the Lord as a thousand years, and a thousand years as one day?"

LUNAR CRATERS.

PHOTOGRAPHS taken from the air of the effect of bomb-dropping on a fairly large scale afford very plausible evidence that the lunar craters are more likely to have been formed by impact than by volcanic action, according to H. E. Ives (*Astrophysical Journal*, Nov., 1919, pp. 245-250). He meets some of the supposed difficulties which have been brought forward in opposition to the bombardment theory: *e.g.*, the absence of similar effects on the earth; the prevalence of the circular shape, and so on, and he replies to the objection that meteors are not explosive bombs, by the argument that the enormous heat generated by a direct collision with the moon's surface, far greater than that which causes fire-balls to explode in our atmosphere without reaching the earth's surface, is more than sufficient to produce all the explosive effect necessary.—*Science Abstracts.*

Did the Babylonian Astronomers Possess Telescopes?*

Their Observations of Venus, Mars, and Saturn

By Dr. Heinrich Hein

THE two planets which stand closest to the sun, Mercury and Venus, when observed through the telescope exhibit a sickle form like that of the moon and for the same reasons. Only one-half of their spherical surface can be illuminated by the sun, and since their orbits are within that of the earth they must necessarily turn towards the earth a larger or smaller portion of their non-illuminated noctural side. Consequently the portion of the illuminated diurnal side of these planets which we are capable of still seeing from the surface of the earth passes through phases like those of the moon. Fig. 1 shows the apparent magnitude and varying form of Venus.

It was in the year 1610 that Galileo first gazed upon Venus with his newly constructed telescope and perceived her sickle-like form. In none of the writings of the ancient Greeks and Romans and in none of the astronomical works of the Arabs is there any indication that anyone before Galileo had ever perceived the sickle form of Venus. It is not until very recently that any uncertainty has been felt as to whether Galileo was really the first discoverer of the phases of Venus. Some years ago, however, the following prophecy was discovered written in cuneiform letters and uttered by some Babylonian astrologer:

"When it cometh to pass that Venus hideth a star with her right horn and when Venus is large and the star is small, then will the King of Elam be strong and mighty, holding sway over the four corners of the earth, and other kings will pay him tribute."

This is then immediately repeated with the exception that the word *right* is replaced by *left* and the name *Elam* by that of *Akkad*. Akkad signifies Babylonia, the arch enemy of Elam, and these two nations were in ancient days (cc. 2,000 B.C.) the only two great powers of Asia Minor, and were engaged in a struggle with each other for the mastery of the world as known to them, i.e., for the rulership over the whole of Asia Minor. The blotting out of a small star by the "horn" of Venus must have been such an extraordinary occurrence as to induce the astrologer to connect with it the greatest prize in his power to offer, dominion over the four corners of the world.

There is absolutely no doubt that the Babylonian word in question signifies horn. Hence it really looks as if the Babylonians had recognized the phases of Venus. But since they had no telescopes they must obviously have perceived the planet's form resembling a sickle with the naked eye. Yet, as we have said, neither the Greeks nor the Romans were ever able to see the horn of Venus although their astronomers studied the planets zealously enough. In the northern part of Europe the evening star was observed very diligently long before Galileo and yet no one ever perceived its phases.

FIG. 1. THE PHASES OF VENUS SHOWING THE CORRECT PROPORTIONAL MAGNITUDES; ABOUT 60″: 55″: 38″: 25″: 16″: 9″.

Hence it has been suggested that the Babylonians must have possessed exceptionally favorable conditions. The air is clearer in that region than in Europe—so clear that bodies upon earth are capable of throwing shadows in the light of Venus—so clear indeed that it is possible to recognize Venus with the naked eye even in the light of day; furthermore, the Babylonians are credited with sharp eyes. A certain Assyriologist assures me indeed that some astronomers have been capable of observing the phases of Venus with the naked eye in the clear atmosphere of Oriental lands.

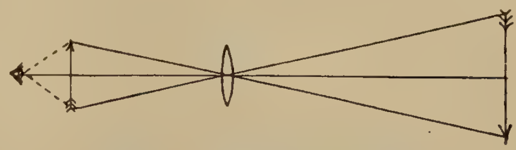


FIG. 2. DIAGRAM OF THE SIMPLE CONVEX LENS EMPLOYED AS A MAGNIFYING GLASS

The reasons thus advanced for the thesis in question are not all entirely satisfactory. Even in Europe Venus is capable of throwing shadows under specially favorable circumstances; likewise, we too can see Venus by daylight when conditions are such that the planet possesses her greatest degree of brilliance and when the observer knows exactly that point of the heavens in which to look for her. Anyone who has ever sought to locate the brighter fixed stars at the first fall of night knows how difficult it often is to find them at first and how readily they can be found again after they have been once located. Napoleon I once saw Venus in the full light of day upon an occasion when he chanced to cast his eye upon the right spot in the heavens and thereafter counted the planet as his special star of fortune. As for the supposed keen eyesight of the Babylonians it certainly seems peculiar that the Arabian astronomers who searched the heavens very diligently in later centuries under exactly the same conditions, had no knowledge of Venus's changing form.

As for myself I do not consider it impossible to perceive with the naked eye a certain degree of elongation in an object of the size and form of Venus when she possesses her greatest brilliance and at a time when she appears both somewhat larger and somewhat narrower (for Venus does not possess her greatest apparent magnitude at the time of her greatest brilliance). But in such a case such an object could not be so bright as Venus, for the reason that very bright objects appear to illuminate the retina over a much larger circumference than is actually the case—they appear to be enlarged. The arc of an arc light is no larger than a candle flame or a gas flame of the kind formerly used, i.e., without a mantle. From a great distance the arc light appears like a brightly radiant disk, whereas the candle or gas flame at the same distance will appear to be merely a yellow point of light. Similarly it is a well known fact that the brighter fixed stars appear to the human eye larger than those whose light is fainter, in spite of the fact that even in the strongest telescopes none of the fixed stars exhibits a perceptible diameter, but they all resemble mere points.[1] It is the same with Venus. Human beings are found rarely free from such a super-exci-

*Translated for the SCIENTIFIC AMERICAN MONTHLY from *Kosmos* (Stuttgart), February, 1920.

[1]It is true also that the brighter fixed stars appear to the human eye perceptibly greater than those whose light is fainter, although none of the fixed stars exhibit a measurable diameter even in the strongest telescopes, and must therefore be recorded as mere points of light.

tation (irradiation) of the retina. One such individual was the astronomer Heis, who was able to recognize Mercury, Venus, and Jupiter in the bright light of day, and who perceived all the fixed stars as mere points, and who was able to distinguish eleven stars in the Pleiades, while the normal person perceives only six, and some few people can see seven or eight. I have never heard that Heis was able to recognize the phases of Venus, but if he could not do so this would weigh against the theory that the Babylonians were able to do so, as it must likewise weigh against this theory that the Babylonians recognized only seven stars in the Pleiades.

Thus it seems to me highly improbable that the Babylonians were capable of observing the phases of Venus with the naked eye, if not entirely impossible. I have, therefore, pondered the question as to whether the Babylonians did not perhaps possess some sort of magnifying instruments. We know that the ancients were acquainted with hollow mirrors, which were used as "shaving mirrors" are among us, to magnify the face and which were also used in Greece, for example, like burning glasses in order to kindle the sacred sacrificial fire by the light of the sun itself. We are told, too, that somewhat later Archimedes kept the Roman fleet away from the harbor of beleaguered Syracuse by means of powerful "burning glasses." It occurred to me, therefore, that the observation of the phases of Venus must have been made possible to the Babylonians by means of the burning glass or hollow mirror. Everyone understands the method by which a burning glass consisting of a convex lens operates. Every one at one time or another has thrown an image of the sun upon his hand with such a glass or burnt a hole in a sheet of paper with it. The distance of the image of the sun from the lens is called the "focal distance" of the lens. At this distance not only an image of the sun is formed but likewise images of all objects which are located at very great distances from the lens. This is readily verified by using a lens at night to experiment with distant sources of light, such as bright windows, lanterns, etc. When the luminous object comes considerably closer to the lens its image recedes from the lens; however, this fact does not here enter into the question.

FIG. 3. MARS IS NEAREST TO THE EARTH: 25″. GREATEST PHASES PREVIOUSLY 13″: 11″; SUBSEQUENT PHASES 11″: 9″

Let us assume for example that the lens has a focal distance of one meter—this signifies that the lens will form an image of the sun at a distance of one meter from itself. But it is likewise true that an object only 100 meters distant will throw an image at the same distance of one meter (practically speaking), but we must remember that the respective magnitudes of the object and the image bear the same relation to each other as do their distances, i.e., in the instances referred to the object will be 100 times as large as the image. Again the diameter of the sun might be calculated with the same laws. The sun is 150 millions km. distant from the earth. Hence if the sun's image is formed at a distance of one meter this implies that the sun is 150 billion times as far from the lens of the image. Thus we need only measure the diameter of the sun's image in millimeters and multiply it by 150 billions and we shall obtain the diameter of the sun in millimeters.

Suppose that the object situated at a distance of 100 meters is a brightly lighted window 100 centimeters high and observed in the evening. The image will be situated at a distance of 1 meter and will be exactly 1 centimeter high. It can be received upon a pane of ground glass. If we now observe the lighted window from a distance of 100 meters and the image from a distance of 1 meter, it is obvious that both will appear of the same size to the eye. (Thus from the view point of the lens the object in the image always appears the same size.) If we now desire to see the window appear four times as large we must approach the actual window until we are only 25 meters distant. However, this fourfold enlargement can be obtained more conveniently by observing the image at a distance of 25 centimeters. Then the image will appear four times as great as the object at 100 meters' distance. If the image has been received upon a screen of ground glass, then it can be observed from either side and the eye can approach the image until the required degree of magnification is obtained. If the image be regarded from the rear side of the ground glass screen—in which case the screen stands between the lens and the eye—the screen may be slowly moved forward. We then observe that the image slowly moves down the screen until it finally hovers freely in space at the same point where it was first found upon the screen (see Fig. 2).

FIG. 4. THE MOST CLEARLY MARKED PHASES OF VENUS AND OF MARS SHOWN IN THEIR CORRECT PROPORTION WITH RESPECT TO MAGNITUDE AND TO BRIGHTNESS: 55″ AND 13″

The matter may be summed up, therefore, as follows: The object at a distance of 100 meters appears to be of the same size as the image at a distance of 1 meter. Since, however, the eye, is not forced to regard the image at the distance of exactly 1 meter, but can without trouble observe it at a distance of 25 cm. it is possible to obtain with a simple lens having a focal distance of 1 meter a fourfold enlargement of objects at a great distance. It is my belief that this use of the simple convex lens as a telescope is entirely new, although such lenses have been employed as microscopes for centuries.

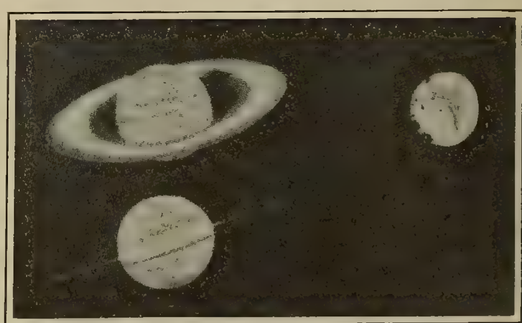


FIG. 5. THE MOST MARKED PHASES OF SATURN AND OF MARS SHOWN IN THEIR CORRECT PROPORTIONS AS TO MAGNITUDE. THE BRIGHTNESS OF MARS EXCEEDS THAT OF SATURN AS MUCH AS THAT OF VENUS DOES THAT OF MARS (FIG. 4). 16″ TIMES 42″ AND 13″

Anyone who has a spectacle lens of very slightly convex form can easily construct a one lens telescope for himself. The only thing required is a cardboard tube. The focal dis-

tance of the lens is first determined, which is readily done by using it to form an image of the sun or the moon and then measuring the distance from the lens to the spot at which the said image is most sharply defined. Suppose that the focal distance happens to be 75 centimeters. Twenty-five centimeters is then added to this and the tube is made 100 cm. long. The lens is inserted at the forward end of the tube and the eye is placed at the rear end in order to observe any given object located at a great distance. It will be found that the said object appears as an inverted magnified image. The field of vision is exactly as large as the lens and is, therefore, of no significance. When an ordinary spectacle lens is employed the image is somewhat distorted. The placing of the eye presents the chief difficulty. The best method is to place a diaphragm in the tube at a distance of about 25 cm. from the eye at about the point where the image would be formed. The eye then has an indication as to where it can be probably best placed. Anyone who has a long telescope tube needs only remove the rear lens, but in this case the eye must generally be placed 15 to 20 cm. to the rear since telescope tubes can rarely be extended to so great a length as is here necessary. It is now obvious that with a lens having a focal distance of 10 meters it is possible to obtain a magnification of 40 diameters. The same thing holds true with regard to concave mirrors as to the double convex lens employed above, with the exception that the observer must look within the mirror instead of through it.

It was not until a considerable time after I had come to the conclusion recorded above that I learned that certain Babylonian texts also speak of the horns of Mars. Since the Babylonians were also accustomed to apply the term "horn" to very slight swellings, it is possible that they had reference to the phases of Mars, though these are small (See Fig. 3).

Under the best circumstances we are able to see only about one-sixth of the dark nocturnal side of Mars. But Mars is so very far distant from the earth that it is probably impossible for the naked eye to perceive the disk distorted. Its diameter is hardly 15″, whereas Venus exhibits a diameter of 55″ at the period when the curved sickle form is plainest to be seen (see Fig. 4). Hence it would be probably impossible for the unassisted eye to perceive a slight elongation of the planet. Thus the Babylonian reference to the horns of Mars likewise raises the question as to whether the Babylonians may not have possessed primitive instruments capable of telescopic observations—a question which I believe can be answered in the affirmative, at least as regards the possibility.

However, in spite of this *possibility* I do not believe that the Babylonians really did make use of the concave mirror as a telescope. Such mirrors must be ground in the form of a portion of a whole sphere, or, better still, in parabolic form. Such grinding requires machines, whereas it is certain that the mirrors ground by hand which the Babylonians possessed were of short focal distance and such mirrors produce distorted images. Then, too, if they were able to recognize the phases of Mars they certainly must also have known something about the form of Saturn. The diameter of the latter is about 16″, and the largest diameter of the ring is about 40″. As we know, the ring disappears at times when we are looking straight at its edge. This phenomenon, that Saturn possesses "horns" which it loses at times should not have escaped the observation of the Babylonians and must have intrigued their imagination. In case records of such observations are discovered with respect to Saturn they would certainly furnish testimony in favor of the Babylonian's use of the concave mirror as a telescope.[2] Until such a text is discovered, however, I shall be of opinion that the mention of the "horns" of Venus and of Mars refer to the phenomena of refraction in the air by means of which the former planet is distorted to resemble a narrow line, which might possibly extend to a small fixed star. Such an occurrence would be an exceedingly rare phenomenon, justifying an extraordinary prophecy.

[2]The late M. W. Meyer mentions somewhere the representation of the planet Saturn with rings by the Babylonians. However, the Babylonians sometimes represent other planets also as surrounded by rings. In my opinion only a direct mention of the rings in the cuneiform text would be convincing. And we must recall, too, how difficult the astronomers of the 17th century found it to recognize the true nature of the rings in spite of the possession of comparatively good instruments.

The Origin of Comets*

Do They Form a Part of Our Solar System?

By Elis Strömgren
Director of the Observatory of Copenhagen

The following article is an abstract made by the author himself, the distinguished Danish astronomer, Prof. STRÖMGREN, *of a longer article published in Scientia (Bologna) for August,* 1918.—EDITOR.

ALL comets known to us have been observed within our own solar system. Our sun is one of billions of suns to whose ensemble the name is given of the Galactic System, and in all probability there are million of systems similar to our own galactic system.

Our little solar system is composed of the sun, of the planets with their satellites, and of comets. It is with the latter that the present article deals and we shall confine ourselves to the study of the following questions:

Whence do comets come and whither do they go? Do they form a part of our own solar system, or are they, as it were, migratory birds coming from afar and folding their wings for but a moment upon the edge of our own little nest in the heavens?

Ever since man has been capable of meditating upon those things which lie beyond his immediate grasp, these questions have exerted a profound attraction upon his imagination. The opinions of astronomers upon this point have long been divided and changing, but today we are in a condition to give a positive answer to the question as to the origin of comets.

The law of gravitation is the basis of all calculations relating to the orbits of the celestial bodies, and if this law were unknown to us it would be impossible to conceive of a discussion of the problem of celestial movements. We are all familiar with the method by which the effect of this force upon two celestial bodies—the sun and the earth, for example—can be demonstrated. The small body, *i. e.*, the earth, is forced to describe an elliptical orbit about the larger body, *i. e.* the sun. Such is the orbit of the earth and such also are the orbits of the other planets.

However, the mathematical study of the problem shows, as every one knows, that the problem of two bodies comprises the possibility of two other kinds of orbits, namely the parabola and the hyperbola. As we know, the ellipse consists of a closed curve while the parabola and the hyperbola are open curves whose branches are of infinite extent.

As a result of this an elliptical orbit in the case of a comet indicates that the comet belongs to our own solar system, while an orbit, which is either paraboilc or hyperbolic indicates that

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the comet comes from outside our system, in other words, from interstellar space. Thus the question of the origin of comets appears to be very simple: if we collect in a single table all the orbits of comets which have been thus far calculated we shall find that a certain number of them form ellipses while others are either hyperbolas or parabolas. From this the conclusion may be drawn that some comets belong to our solar system while others come from outside. Yes! the problem *appears*, indeed, to be very simple, and it is in this simple manner that astronomers treated it until about twenty years ago. But the matter is in reality far more complex, as we shall presently see.

* * * * * *

In speaking of the "problem of the two bodies," and of the explanation of the orbits of planets and of comets, we have intentionally neglected a point which is of very great importance with respect to the making of *exact* calculations. We know how the attraction of the sun causes a planet such as the *earth*, for example, to describe an ellipse around the sun. We can also prove in the same manner that the planet Mars describes a similar orbit around the Sun. But in reality besides the attractions which are exerted between the Sun and the Earth and between the Sun and Mars there is a mutual attraction between the *Earth* and *Mars*, and in spite of its relative insignificance this force deranges the motion of the two planets, which would otherwise be purely elliptical. These small derangements in the elliptical movements of celestial bodies are termed *perturbations*.

The calculations of the *perturbations* undergone by the movements of the planets has formed the principal problem of theoretic astronomy for the last two centuries. But this brings us to an important point in the problem of comets.

The orbit of a comet which has been calculated by the aid of observations of the said comet cannot be looked upon as valid, in fact, except for a certain period of time, namely, that period during which the comet has been observed, *i. e.* while it was in the vicinity of its perihelium, for the easily understood reason that the comet is not visible from the earth at a point beyond a certain distance from the perihelium, either while approaching or while departing. It is in this manner, *i. e.* by the aid of a very small portion of the orbit that orbit after orbit has been calculated. In the course of time a table has been obtained which contains several hundred orbits of comets, and this table has formed the basis of all the conclusions which have been drawn concerning the origin of comets.

No one had ever raised the question as to whether the most interior portion of the cometary orbit is really a true expression of the manner in which the comet entered *originally* into the interior portions of our solar system. It is only some twenty years ago that the following very simple questions occurred to anyone: Have not the large planets of our solar system exerted an appreciable influence upon the orbits of comets during the long period of time which has been required by them to enter the internal portion of our solar system? And is it not possible that this influence might be great enough to change an orbit which was originally elliptical into a hyperbolic orbit and vice versa? And if this be true must not the problem of the origin of comets be reconsidered?

Let us consider the matter more nearly. Among the various qualities which characterize an ellipse a parabola or a hyperbola there is one which is particularly important with respect to our present problem. It is that which might be called the *degree of elongation*. Astronomers and mathematicians call this the *eccentricity* of the orbit and designate it by the letter E.

In order to state the matter clearly let us set down the following figures:

1. A circle has no elongation. Hence we say that its eccentricity E equals 0.
2. In an ellipse E may have all the value comprised between 0 and 1.
3. In the parabola E equals 1.
4. In the hyperbola E is greater than 1.

If we have calculated the orbit of a comet, therefore, by the aid of our observations and have obtained as a result: E = 0.999,500, this signifies that the orbit is elliptical and if we have obtained as a result: E = 1.000,500 this means that the orbit is hyperbolical.

But among the numerous orbits which have been calculated there are as a matter of fact a great many cases in which the eccentricities are found to be in the vicinity of unity, the majority being a little bit less than 1 while the others are a little bit more than 1. And we know by the foregoing observations the fundamental difference which exists, from the point of view of cosmogony, between those cometary orbits in which the eccentricity is a little less than 1 and those in which it is a little more than 1. In the first case the comet must belong to our solar system, while in the other case it must have come from outside.

But let us now return to our original point of departure: The orbit which has been calculated by means of our observation, *i. e.* by the aid of its most interior portion, cannot be exactly the same as the orbit possessed by the comet in those portions which are exterior to our solar system. It is necessary therefore to calculate the perturbation. It is necessary to see what was the degree of eccentricity of the orbit when the comet was far away from us. Such researches have been carried on during the past twenty-two years and the results to which they have led can be summed up in the following manner:

If one follows for a sufficient length of time the different comets in their passage towards the exterior one finds that not a single hyperbola remains. The cometary orbits which were hyperbolic in the internal portion of the solar system acquired this hyperbolic form by reason of the perturbations to which they were subjected by the planets.

Here then we have the answer to our questions regarding the origin of comets: *Comets belong to our own solar system*, and whereas in former times astronomers believed themselves obliged to distinguish between *periodic* comets and *non-periodic* comets, we speak today only of comets which have *short periods* and those which have *long periods*.

* * * * * *

Various arguments have been proffered in contradiction of this theory that comets belong to our solar system. Various authorities have attempted to discover, by the aid of statistical methods, systematic peculiarities in the movements of comets. For example, the question has been debated as to whether the planes of cometary orbits in space are grouped in a special manner—or whether there are special points in the heavens whence comets appear to come by preference and it has been suggested that such peculiarities in the movement of comets might show that comets enter our system from outside it.

But as for the first point it has been demonstrated by Holetschek that a multitude of such peculiarities in the movements of planets are only *apparent*—for they can be explained by means of conditions which inhere in the observations which have been made with regard to the Earth; furthermore, all things considered, we are not able to imagine any systematic peculiarities belonging to the orbits of comets which cannot be explained by the theory that comets form a part of our solar system. Even if, for example, we are able to demonstrate that comets come principally from particular areas of the sky it is quite useless to suppose that they have departed from certain locations in space external to our system in order to enter this system. The fact is explained quite as well by the highly probable supposition that in distant localities *situated within our nebulous regions* there formerly existed concentrations of nebular matter which latter gravitated toward the center. Hence the existence of such systematic peculiarities in the movements of comets cannot prevail against the positive proof which we have here given that comets belong to our own solar system.

LAST OF THE ONCE FAMOUS "MOUND CITY" THREE MILES NORTH OF CHILLICOTHE, OHIO

Remains of the Mound Builders in the Scioto Valley

Curious Earthworks That Are Being Destroyed by the Ravages of Civilization

By R. W. French

WITHIN the confines of the State of Ohio and notably in Ross County along the valley of the Scioto River and its tributaries were at one time numerous remains of the Mound Builders, or Indian Mound Builders, so styled from the nature of their remains; while today few remain, even some of the largest having disappeared before the plow, village and city of a modern people and civilization. At one time a few minutes' travel in almost any portion of this great valley brought the visitor to one of these more or less interesting remains, either mound or fortification, while today it often takes quite a little traveling to find one or two that have sensibly escaped the ravages of modern man.

Chillicothe, county seat of Ross County, was once the scene of several Indian villages and within the corporate limits of that town there were no less than ten mounds and six enclosures, or earthworks, the work of a bygone and little known people; today only two of the mounds and none of the earth-works are discernible and one of the remaining mounds is fast disappearing to supply earth for fills where desired.

A mile and a half to the north of Chillicothe was the so-called "Mound City," the exploration of which supplied much of the information obtained regarding the people who left these interesting remains for the study of the archaeologist. The first explorers of this group reported that there were no less than 24 mounds within the enclosing earthwork. Today this area, which is a portion of Camp Sherman, U. S. Army cantonment, is practically devoid of any vestige of mound or enclosure. One mound remains within the cantonment and this was outside of the enclosure.

The remains of the Mound Builders are found on both the high and low ground, but the more extensive works and larger mounds, as a whole, occupy the flat land in the valleys; all of which accounts for their early decadence before the plow of the farmer. In certain instances, such as Fort Hill, Spruce Hill and Fort Ancient, hill tops were enclosed, apparently for the purpose of defense, and to afford places of refuge in case of attack. Many of the higher eminences are crowned by small mounds generally supposed to have served for signal fires with which information was passed from village to village, rather than as tumuli, such as the larger mounds in the valleys are generally found to be.

These lesser mounds have escaped destruction generally, their sites not being arable and being more or less heavily wooded. These works are often so small as to be hardly recognizable as such, a close survey of the hilltop being necessary to determine the artificiality of the crest.

Of the more important groups, one known as the "Hopewell Group," about four miles west of Chillicothe on the North Fork of Paint Creek is today a well cultivated field and few of the original twenty-six mounds reported by the first explorers remain other than as slight rises in the ground, many

LARGE MOUND HALF A MILE SOUTHWEST OF BAINBRIDGE. ITS SIZE CAN BE JUDGED BY COMPARISON WITH THE FIGURES IN THE FOREGROUND

MOUND ON THE FAIR GROUNDS AT CHILLICOTHE. THE LARGE LOCUST NEARLY 3½ FEET THROUGH AT THE BUTT GIVES SOME IDEA OF THE AGE OF THIS EARTHWORK

THE SEIP OR PRICER MOUND NEAR BAINBRIDGE ON THE BANKS OF PAINT CREEK

SMALL MOUND NEAR CHILLICOTHE THAT IS STILL IN A GOOD STATE OF PRESERVATION

years' cultivation serving effectually to cut them down. This is likewise true of the earthwork formerly enclosing these mounds.

This group supplied a great deal of information to archaeologists, many implements, both stone and copper, as well as a number of skeletons being recovered in the excavation of these mounds. From one mound more than eight thousand flint disks were removed. These disks were found in pockets of twelve or fifteen each with a layer of sand between each pocket. The weight of this cache was more than three tons.

Twelve miles southwest of Chillicothe, near Bainbridge, Ohio, there are several well preserved mounds. One of these, known as the Seip or Pricer mound from the name of the people on whose land it stands, has not been opened; the owners refusing permission for its exploration. At one time there were several other mounds in the immediate vicinity, but today no remains are noticeable.

Between Chillicothe and Bainbridge on Paint Creek is the hill-top fortification of Spruce Hill. The work overlooks the hills along the Scioto River to the east of Chillicothe as well as many miles to the north and south of its site. The hill has steep, in some cases almost precipitous, sides; and is a spur projecting from a table land to the south. The enclosure is formed by a wall of stone which closely follows that margin of the nearly level summit. The material for the wall was procured near at hand from several rock outcroppings which are common to this part of the state. The wall is continuous except for several breaks to the south, where it crosses the table land. These breaks were apparently left for gateways.

The remains of this wall is badly overgrown by timber, but its site is easily traceable by the many stones scattered about. At no place are the stones in a semblance of a wall, though the scattered stones cover the ground to a thickness of several feet; judging from the amount of material on the ground and the steepness of the slope it should have been easy to defend the area against invasion by hurling stones or other missiles on the heads of the attackers. This wall is said to enclose the largest area in the world enclosed with a wall entirely constructed of stone.

Of the remains in the proximity of Chillicothe, no doubt the most famous is the Serpent Effigy Mound, 40 miles to the southwest in Adams County. This is one of the most striking effigy mounds known and a visitor is impressed of the artificiality of this remains at the first view. Over all the mound is more than 1,300 feet long and depicts a serpent of several convolutions, jaws extended and an oval within the grasp of the huge jaws.

This effigy is situated on a precipitous point of land near the junction of the east and west forks of Brush Creek; and skirting Brush Creek is so precipitous as to prevent scaling from that direction, while from the opposite side the ascent is fairly gradual.

On coming up the slope the visitor sees the tail commencing with a small terminal pit. Following the earthwork, which is from two to four feet in height and from three or four feet to 20 feet in thickness, we follow the unfolding coil for two full turns, then advance along the body which gradually increases in height and width with three large folds and ending in the extended jaws and lastly the oval earthwork, detached from the body proper.

The meaning of this earthwork has caused not a little speculation among students of archaeology and even today with the study of several remains that have been unearthed from time to time its purpose is not definitely settled. Within the oval an altar of stones was discovered and remains of cremations and copper ornaments. This, however, has only served to increase the several arguments regarding the reasons for the effigy, which is so striking, and which is in no way duplicated anywhere in this region of the United States.

The antiquity of the mounds is not known. Some Indian legends have it that they were in existence at the time of the Indian and that they were then heavily overgrown with trees

MOUND THAT HAS BEEN CUT TO SUPPLY DIRT FOR FILLS, SHOWING HOMOGENEOUS NATURE OF MATERIAL COMPOSING IT

MOUND ON LICK RUN, FOUR MILES SOUTHEAST OF CHILLICOTHE, WELL PRESERVED BECAUSE THE LAND IT OCCUPIES IS NOT ARABLE

VIEW OF THE SERPENT EFFIGY MOUND, SHOWING THE THREE BROAD FOLDS OF THE BODY AND IN THE DISTANCE THE OVAL WITHIN THE EXTENDED JAWS

NEAR VIEW OF THE SERPENT EFFIGY MOUND, SHOWING THE SIZE OF THE EARTH WORK. IT IS 1,300 FEET OVER ALL, 20 FEET WIDE AND 2 TO 4 FEET IN HEIGHT.

which would make them very old within the time of the Indian. Other legend has it that the Mound Builders were a race distinct from the Indian and that the latter overcame them and destroyed them. Other claims presented are that they are a branch of the Aztecs of Mexico or other races of the Southwest.

However, an analysis of the remains fails to confirm or disprove any of these assertions beyond a shadow of doubt. In many respects the remains show no connection between the civilization of the mound builder and that of Europeans, tending to show that the works are pre-Columbian, while at the same time, in many ways there is no material difference between the works found in the tumuli to cause any great distinction between the work of these people and the Indians. Both stone and copper implements have been unearthed in considerable quantity, but in nearly all instances work of the same type and nature is connected with known work of the later Indian races.

The copper is thought to have been obtained from the large deposits in the Lake Superior region, as those mines show evidence of having been worked by aborigines many years ago. If this is true, a considerable traffic was no doubt developed by these people. That, though, can be accounted for largely by migratory trips in the summer to the copper regions, or by exchange between various tribes; the latter no doubt the more probable, inasmuch as barter is a well-known trait of the early American.

Of written history, hieroglyphics or pictures, practically none remain, and of the remains none have any tendency to dispel the general gloom regarding the history and civilization of the mound builder. With the rapid destruction of the remains and the fact that early exploration was not carried on in the systematic manner pursued by the archaeologist today it seems little likely that the question of antiquity and origin of this race will be deciphered. Furthermore people that are interested in seeing these remains in situ will have to make haste as time and the ravages of modern civilization are fast removing the last vestiges—where there were thousands of mounds and earthworks yesterday, there are barely hundreds today.

FIGHTING GRASSHOPPERS WITH FLAME PROJECTORS

THE agricultural regions in the southern part of France suffered considerably from the grasshopper plague during 1918 and especially in 1919, when the *Dociostaurus marocanus* insects multiplied to an extreme degree. Other districts in France suffered from the *Calliptamus italicus*, while the northern part of Africa was invaded by the *Schistocerca tatarica.* The French Government recently sent three official expeditions to these regions, one to Morocco and two others to the southeast of France in order to investigate the nature of these insects and their depredations, and especially to find out the best means for their extermination. A prominent agronomist, P. Vayssière, was actively engaged in this class of work, and we are indebted to him for the present account of the various researches which were made during the year 1919, especially in the great plains region of the Crau. The Department of Agriculture in fact proposed to make use of different destructive methods or products which had been brought out during the war. The tests included in the first place the use of flame projectors devised according to army practice. Heavy coal oil is the fuel employed, and the apparatus is found to give remarkable results against swarms of grasshoppers either at rest or moving along the ground. Insects touched by the flame or stationed on an area of about 3 feet around the burned surface are instantly killed. With one filling of the apparatus of some 12 liters' capacity, a surface of over 200 square meters can be treated. It is preferable to use two or three apparatus in line, so as to cover a zone of 100 square meters in a very short time. The second method consists in the use of toxic gases which suffocate the insects, and the experiments bore upon two such gases; one was a mixture of oxychloride of carbon and chloride of tin, which was considered during the war as highly poisonous to man and animals, but it did not seem to act to any extent upon the numerous swarms of grasshoppers, even though they underwent the action of very concentrated gas at distances from 0.10 to 4.0 meters from the outlet. On the contrary, excellent results were obtained with an atomizer spray of chloropicrine in aqueous emulsion at 25 or better at 50 per cent. When touched by the sprayed drops, the insects in all cases died within a few seconds. This compound does not appear to burn the vegetation to any great extent, as it is seen to flourish again in a few weeks. Further investigation is in order upon this subject in the south of France. The author also made use of bait in the shape of arsenical salts made up with bran, using only 0.5 kg. of arseniate of soda for 12 kg. of bran, and this was hand-sowed on meadow land covered with grasshoppers. Twelve hours afterward, it was found that great numbers were poisoned, and within 48 hours about 80 per cent were destroyed. He covered over 500 square meters of ground in this case. As a result of all these tests, it is considered that the grasshopper plague can be fought very effectively, especially when we have to do with swarms of young larvæ. The three methods can best be employed as follows: Flame projectors upon all ground where there is no danger of fire; atomizers with spray using highly concentrated solution of chloropicrine in all cases where flames would prove dangerous; arsenical bait upon irrigated prairie land where animals do not pasture.

Insect Foes of Books

The Bookworm Past and Present

WHAT *is* a bookworm? In other words what image rises in the reader's mind when he hears the word? Very probably the picture flashed upon his mental screen is that of some bespectacled Doctor Dry-as-Dust Dominie Sampson poring diligently over learned volumes. But such a picture is obviously one derived from a secondary meaning of the word. What then is a *real* bookworm? How big is it? What is its shape? What is its nature? What are its colors, and what are its habits, aside from its predatory predilection for books? Doubtless nearly everyone who reads these lines has a pretty clear mental image of an earthworm, a silkworm, a "measuring worm," a tobacco worm, a cabbage worm, etc., etc., but how many are capable of describing a bookworm?

WHAT BOOKWORMS REALLY ARE.

To begin with, it must be remarked that bookworms are not really worms at all in the scientific sense of the word "worm"; they are something quite different according to the best authorities, being really insects of various sorts, either in the adult state or in the larval state. In the latter stage of life, i.e., as larvæ, they do, of course, much resemble true worms to the non-informed.

The truth is that the word bookworm has been very loosely applied for many centuries to any sort of living organism, living in or preying upon books. The first mention, perhaps, of the bookworm is in a passage from Aristotle, which reads as follows: "In old wax, as in wood, there is found an animal which seems to be the smallest of all creatures, called acarus. It is small and white, and in *books* there are others like those found in cloth, and they are like scorpions without a tail, the smallest of all." This insect has been plausibly identified with the *acarus cheyletus* of the order *acaridae* which is described by F. J. X. O'Conor, of the College of St. Francis Xavier, New York, as being "extremely small, hardly visible to the naked eye, pink in color, and corresponding perfectly to Aristotle's description." This authority, however, thinks it highly unlikely that this minute creature does any real damage to books, though often found in them.

But why should insects of any kind haunt books at all, and when and why did they acquire this taste? These questions are easily answered, for no matter how barren of intellectual wealth a book may be, and how unattractive to the human bookworm, it is a rich storehouse of varied food for such creatures as are capable of assimilating the cellulose of its paper, the wood and leather of its binding, or the gluten and starch of the paste that binds its pages together. Hence the wood-eating (Xylophagus) insects which live on the wood of trees as well as the ordinary cockroach and "water-bug" which feeds on starch and gluten, and all those insects which, like white ants, are capable of feeding on cellulose, find in a book a well-stocked larder and in a library mountains of provisions such as Joseph heaped up for the Egyptians in the seven fat years of plenty, that came before the seven lean years of famine.

Among the commonest of the insects known as bookworms are the larvæ of the Coleoptera or sheath-winged beetles, Seven varieties of these have been found in books in this country by F. J. X. O'Conor:

1. *Sitodrepa panicea*, larva.
2. *Attagenus pellio*, larva.
3. *Sitodrepa panicea*, full-grown insect.
4. *Lepisma saccharina.*
5. *Ptinus fur.*
6. *Dermestes lardarius.*
7. *Anthrenus varius*, larva.

Sitodrepa panicea, larva.—"The most voracious of these beetles is the *Sitodrepa panicea*, of which I have examined," says Mr. O'Conor, "thirty specimens. Here in New York I have found it as well as in Washington. In the larva form it is a soft, white six-legged worm covered with bristles. It is about ⅛ of an inch long and moves very slowly."

This little creature is worth a lengthier description since it is not only voracious but practically omnivorous. In Europe it is still known as the bread beetle from its occurrence in dry bread, but it by no means confines itself to bread and books. In this country it is commonly known as the drug store beetle, since it plays havoc with the pharmacist's supplies. The division of Entymology in the United States Department of Agriculture some years ago honored this active depredator with a special bulletin, to which we are indebted for the following description of its aspect and habits:

This beetle is a member of the family Ptinidae. It is cylindrical in form, measuring about a tenth of an inch in length, and is of a uniform light-brown color, with very fine silky pubescence. The elytra are distinctly striated and the antennæ end in an elongated three-jointed club. When at rest the head is retracted into the peculiar hoodlike thorax and with the legs and antennæ folded under and tightly appressed to the body, the little creature easily escapes observation. The larva is white, with darker mouth, and of a cylindrical curved form. The pupa is white.

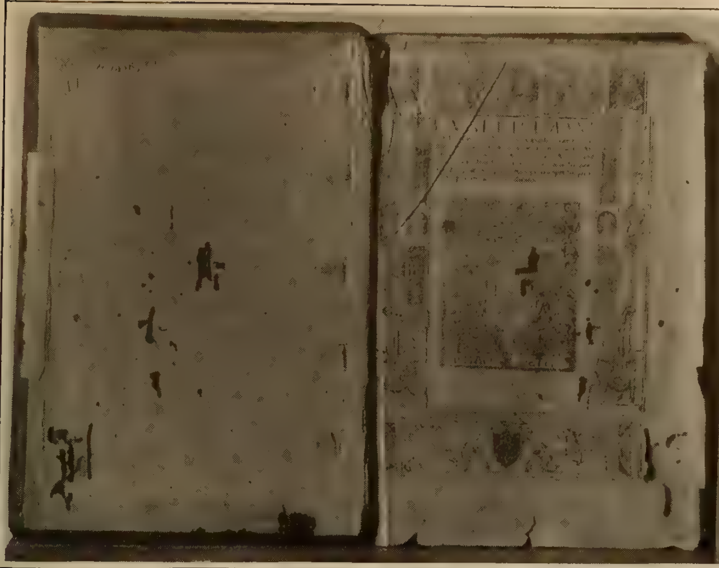
It invades stores of all kinds, mills, granaries, and tobacco warehouses. Of household wares its preference is for flour, meal, breakfast foods, and condiments. It is especially partial to red pepper, and is often found in ginger, rhubarb, chamomile, boneset, and other roots and herbs that were kept in the farmhouse in our grandmothers' day. It also sometimes gets into dried beans and peas, chocolate, black pepper, powdered coffee, licorice, peppermint, almonds, and seeds of every description.

The subject of injuries wrought by this species has formed the text of a considerable literature going back to the year 1721, when Pastor Frisch found the larva feeding upon rye bread, and including, besides damage of the nature referred to, injury to drawings and paintings, manuscripts, and books. Some singular instances are recorded of the injury it does as a bookworm. The late Dr. Hagen wrote that he once saw a whole shelf of theological books, two hundred years old, traveled through transversely by the larva of this insect, and still another record is published of injury by the species *Ptinus fur* to twenty-seven folio volumes, which it is said were perforated in a straight line by one and the same insect, and so regular was the tunnel that a string could be passed through the whole length of it and the entire set of books lifted up at once.

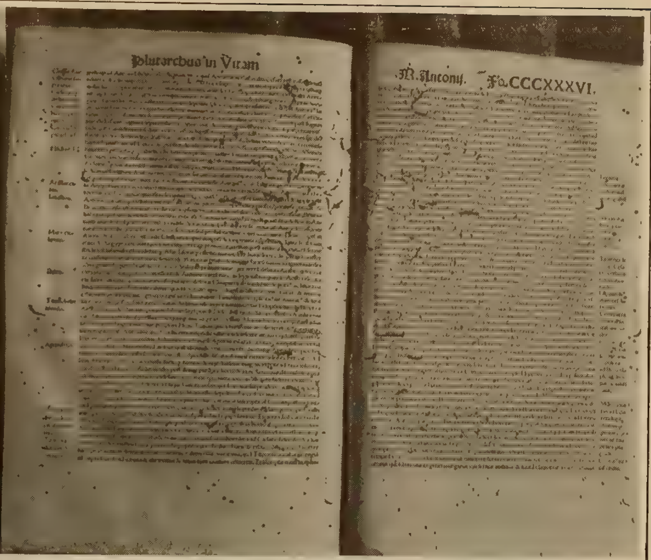
In pharmacies it runs nearly the whole gamut of everything kept in store, from insipid gluten wafers to such acrid substances as wormwood, from the aromatic cardamon and anise to the deadly aconite and belladonna. It is particularly abundant in roots, such as orris and flag, and sometimes infests cantharides (Spanish flies).

It is recorded to have established a colony in a human skeleton which had been dried with the ligaments left on, and the writer has seen specimens taken from a mummy. It has even been said to perforate tinfoil and sheet lead, and that it will eat anything except cast iron. In short, a whole chapter could be devoted to the food materials of this insect, as nothing seems to come amiss to it and its voracious larvæ. The subject may be concluded with the statement that this division has received complaints from four different correspondents, of injury to gun wadding, and there are several records of injury to boots and shoes and sheet cork.

The larvæ bore into hard substances like roots, tunneling them in every direction, and feed also upon the powder which



TUNNELS BORED IN OLD BOOK BY THE DERMESTES, KNOWN IN FRANCE AS THE "GIMLET" FROM THE REGULARITY OF THE HOLES IT MAKES



PAGES OF AN OLD BOOK IN THE BIBLIOTHEQUE DE L'ARSENAL, RIDDLED BY THE BOOK-EATING LARVAE OF VARIOUS INSECTS

soon forms and is cast out of their burrows. In powdery substances the larvæ form little round balls or cells, which become cocoons, in which they undergo transformation to pupæ and then to the adult insect. I have reared the insect from egg to beetle in two months, and as it habitually lives in artificially heated buildings and breeds all through the winter months, there may be at least four broods in a moderately warm atmosphere.

In France the *sitodrepa panicea* is known as the *anobium paniceum*, and the great French authority Houlbert, the author of *Les Insectes Ennemis des Livres*, a book which won one of the prizes offered at the International Congress of Librarians held in Paris in 1900, declares that in France nine-tenths of the injury done to books proceeds from this unpleasant pest. It is not generally known that the sound made by this insect, which resembles the monotonous ticking of a time-piece, has earned for it from the superstitious the name of the Death watch. The well-known French entymologist, the Abbé Plessis, gives an entertaining account of the death watch which should rather be called the Love watch, since the sound is really the mating call of the insect. He says: "One day one of my pupils brought me an anobium which I placed for a few days in a light box on my table. It occurred to me to knock upon the table with my penholder and the insect promptly answered me. At the end of a few days, when it had become accustomed to its surroundings, I took it out of the box and placed it upon my table where I and many others observed this curious action. This insect is gifted with a singular elasticity between the head and thorax. It makes its knocking sound by bending its head entirely underneath the thorax and then knocking with the top of its head."

The *anobium tessellatum* and the *A. Pertinax* are likewise guilty of depredations. Because of the extreme regularity of the tunnels bored by these insects in wood or in books, they are commonly called "gimlets" in France. Their presence in a room can be detected by small heaps of a reddish powder, lying upon shelves or furniture or on the floor. Where such *dejecta* is observed means of extermination should promptly be applied.

The *anobium hirtum* is found occasionally in the center and south of France though not in England. It is more common in the southern part of the United States, large numbers having been found in the State Library in Louisiana.

Attagenus Pellio.—This insect, which appears to be rather rare, is described as looking like a miniature whale under the microscope. It is long, slender and salmon colored, with a tail of delicate wavy hair. It is very graceful in its motions.

Lepisma saccharina.—This insect, which is to the present writer at least, most repulsive in aspect, both as to form and color, is commonly known "as the silver fish; or sometimes as the silver louse, the sugar fish, etc. It seems to have been first mentioned in literature in Robert Hooke's *Micrographia*, published in London in 1667, in which he describes vividly the "small silver colour'd book-worm, which upon the removal of Books and Papers in the summer, is often observed very nimbly to scud, and pack away to some lurking cranny."

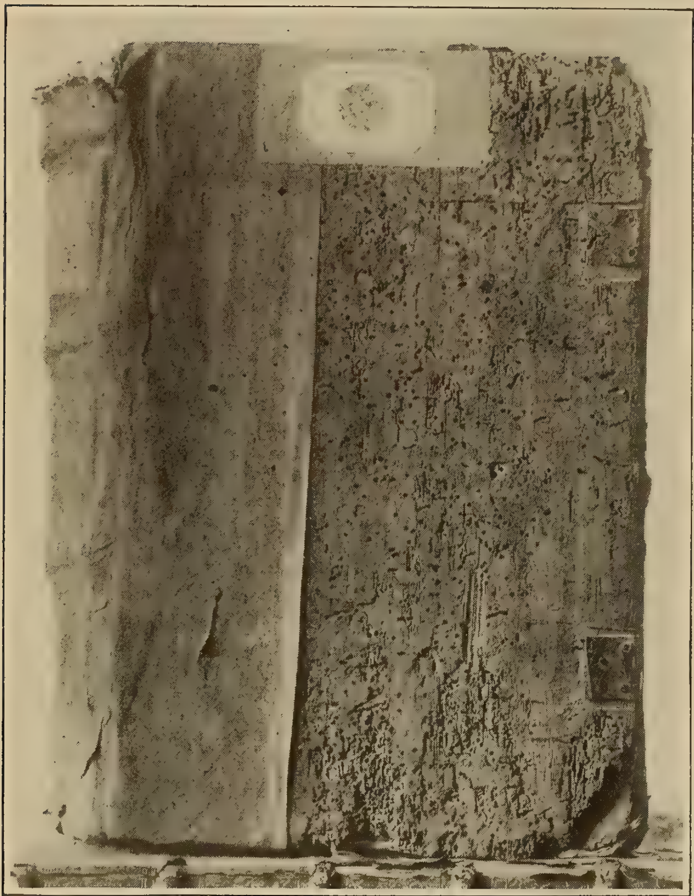
Hooke also gives a drawing of the silver fish, clearly showing the spindle-shaped or carrot-shaped body and the distinctive three bristles at the tail. In color it is, to the writer's eye, at least, of a peculiarly unwholesome livid gray, with a silvery gleam due to its shining scales. C. L. Marlatt describes it as being one of the most voracious devourers of books, papers, labels, etc., and sometimes of ordinary food. It is also said to feed upon Neuroptera of the genus Psocus. The head is large and blunt and the body tapers uniformly towards the tail.

A close relative of the *Lapismax saccharina* is the *Lapisma domestica* first described in 1873 by Packard and sometimes called the *Thermobia domestica* Pack. This insect is common in bakeries and shows a strong liking for heated localities in general. It is very common in Washington, D. C., and probably elsewhere in the United States. This insect is sometimes trapped in a very simple manner as follows: A box with a handle and having small holes punched along its lower edge is set upon a low support. Within the box are placed piles of paper fragments covered with starch paste and the trap is then placed in a dark corner of the library. The odor of the paste attracts large numbers of insects which find themselves unable to escape and which can be burned from time to time.

Ptinus fur.—This is a black-headed "worm," or rather larva, which is found in great numbers and is said to be "willing to eat anything." It resembles the *Sitodrepa* with the exception of the bristles and shape of the head as well as the color of the body. The adult is known as the white marked spider beetle. It is active chiefly at night when it can be found moving slowly along walls and wainscots. Chittenden relates the extraordinary fact that this insect was discovered to have devoured more than a hundred bags of cotton seed stored in a barn and had multiplied in such large quantities as a result of this rich provender, that it afterwards invaded neighboring houses, attacking clothing and organic material of all sorts. In America this insect is capable under favorable conditions of producing three generations annually.

Dermestes lardaria.—The *Dermestidae* are well known as

consumers of dried animal remains, of plants, and of furs, and many a collector of moths or of butterflies has suffered from the ravages of this little "worm" which will devour anything from a live insect to hard sole leather. In appearance the *Dermestes lardarius* may be compared to a microscopic hedgehog, bristling all over with rough black hairs. Even with a microscope of high power one finds it difficult to determine at which end of the hairy body is the head. Among books this species will be found in great numbers. They leave, especially upon the covers, rougher marks than are made by the other insects here mentioned. O'Conor gives an entertaining account of his first acquaintance with this little creature which we quote from his admirable brochure *Facts About Book-Worms.*



TUNNELS MADE BY THE DERMESTES LARVAE IN THE WOODEN BINDING OF A XVTH CENTURY BOOK

"On a summer's day, in the venerable Georgetown Library, where it seemed that the old times had kept within them the odor of past ages, as I held in my hands an open folio bound in leather, a little ridge of dust along the inner edge of the binding attracted my attention. On closer examination I found small holes near the edge of the dust heaps. Taking a penknife I raised the paper on the inside of the cover. When behold! there before me lay a little brown insect. It was covered with bristles and looked for all the world like a tiny hedgehog, curling himself in his spikes to insure protection. I continued the investigation, and in the same book soon found another, his counterpart. Here was a discovery in truth! 'This must be a book-worm,' I thought. . . .

"I had chanced upon the real, living, visible, palpable creature. A true book-worm visible to the naked eye it was, and it was possible that there were others that might be found under similar conditions. There was a thrill of satisfaction in the thought that I could verify a word that seemed to have hovered on the borderland of fact and of fiction, and to inquiry about which no satisfactory answer had yet been given in the domain of letters. . . .

"With a microscope I studied the movements of my captive strangers. I watched them as, on their backs, they clutched at the empty air with their six small claws, or buried their heads in the paper that I had placed near them to entice them to make use of their mandibles. They were evidently in no humor to do much boring, as very little was effected during their days of captivity. These two specimens were the *Dermestes Lardarius*, or larvæ of the brown beetle. . . ."

The *Dermestes lardarius* is known as the larder beetle in English and sometimes by the name of the bacon beetle in France and Germany. This insect is readily distinguished from all other species of the same group by the striking coloration of its elytra or wing cases whose upper portion is crossed by a large whitish band decorated with six black spots. The adult insect, which does but little damage, is about 68 mm. in length; in shape it is an elongated oval; the thorax is as wide as it is long, being rounded and tapering towards the front; it has short antennæ ending in a sort of "club" with three joints. The legs are retractile.

As we have said, this creature is particularly fond of leather and dried skins. During the warm months of the year the females deposit their eggs in the inside of bookbindings, generally on the ridges or edges which are in contact with walls or shelves. As soon as the larvæ are hatched they slip inside the volumes and begin their destructive feast upon the latter. It is a curious fact that the larvæ are much larger than the adult insects. They have elongated bodies somewhat spindle-shaped in form and ending in a truncated cone furnished with two curved "horns." The skin, which is extremely hard, and coriaceous is chestnut brown on top and yellowish white beneath. It is covered with long red hair, bristling like the quills of a porcupine. Its head is rounded and scaly with two small antennæ and six small ocelli on each side. The body, including the head, contains thirteen segments. The mandibles, which are "toothed," are extremely strong. During its period of growth, which is very rapid, the larva "moults" four or five times, the discarded integument remaining stretched like a blown-up balloon, so that it closely resembles the larva itself except that it is transparent and paler.

The young larvæ do not excavate regular tunnels like those of the *Anobiides;* on the contrary, they travel hither and thither according to caprice, thus producing quaint and intricate patterns or arabesques on the covers of books. This richly decorative, if destructive, effect is shown in our illustrations.

The adult insect generally enters houses in May or June for the purpose of laying its eggs. A close relative of similar habits is the *Dermestes vulpinus* or "fox beetle."

Anthrenus varius.—This larva is oval-shaped, and varies in form between the almost round *Dermestes* and the elongated *Attagenus pellio.* Like the *Dermestes,* it prefers the bindings of books, while the *Sitodrepa* and *Ptinus* take kindly to the paper.

This insect is commonly known as the carpet beetle but it is extremely adaptable and is quite willing to live on furs and other clothing, upon upholstery, and upon books, according to circumstances; likewise it readily adapts itself either to indoor or to outdoor life. Out of doors it is principally found among the flowers of the *Verbascum.* Whether indoors or outdoors it is found from March to October. In heated houses its eggs continue to hatch all through the winter and the spring.

It is a fortunate circumstance that the larvæ of these insects are attacked by certain parasites, Ichneumonidae. E. Olivier mentions a small Arachnid, red in color, which lives in the dust which collects on bookshelves and in wardrobes, and which makes an active hunt for these larvæ; he has even seen such a spider seize and devour an *Anthrenus* larva much bigger than itself. It seems probable that one or the other of these natural enemies might be used to keep this pest in check.

All of the *Coleoptera* described above have been actually

found in the libraries of the United States by Mr. O'Conor, and this is especially interesting in view of the fact that the standard authority on the care of books, Mr. William Blades, has assumed that the great damage done in libraries by book-worms is mostly a thing of the past, believing the adulterations of modern paper to be the reason for this, and remarking that "his instinct forbids him to eat the China clay, the bleaches, and the scores of adulterants now used to mix with the fiber." Mr. O'Conor, however, gives many specific instances of recent damage done by book-worms. The following passage from his monograph is of special interest:

"On another occasion I surprised the worm at work on bound volumes of the SCIENTIFIC AMERICAN of the years 1873 and 1875. Professor Riley, to whom I reported these facts, agreed with me that the claim that only old books were in danger and not recent books of modern paper, could not be maintained in face of such testimony. Therefore the theory of Mr. Blades that the book-worm will not eat modern paper vanishes into thin air, but the destructive work continues. It must be admitted as true that the older books run the greater risk for they are less used. . . . No true book-worm would deign to touch a popular novel. But from the security of new books a librarian may unwisely argue that older and more valuable volumes are untouched."

OTHER INJURIOUS INSECTS.

Book-mites and book-lice.—The book-louse, which when without wings is called in America the book-mite, belongs to the family of *Psocidœ*. Its most essential characteristic is in having wings with very few ribs. The mandibles are very strong and dentated on the inner edge, while the jaws are provided with a crushing device. All of these insects live upon dried plants and organic matter of all sorts. In spite of their very small size their habits closely resemble those of the destructive white ants or termites—five species are known.

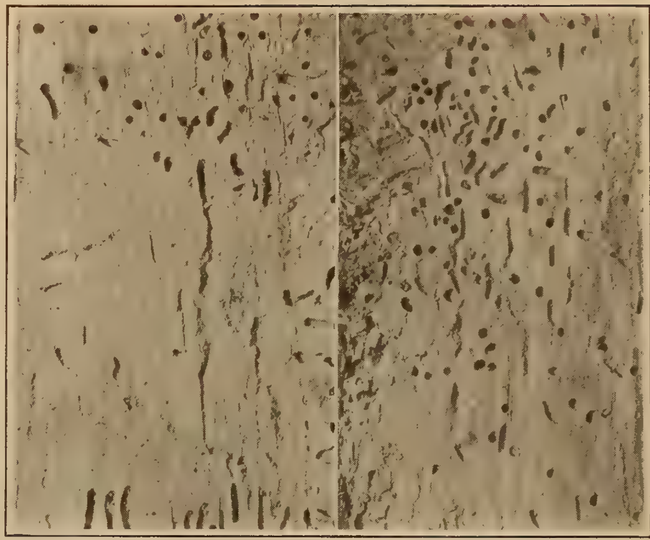
Ants.—Some species of ants, e.g., the *Lasieus fuliginosus* make their nests of paper, and for this purpose they gnaw into fragments the leaves of books to which they have access.

Clothes moths.—Clothes moths are all small *Lepidoptera* of nocturnal habits. The frequency with which they singe their wings at lamps or candles has become a proverb. They are pretty little creatures of various colors covered with an iridescent "bloom" or dust. The four most dangerous species are the *Tinea tapetzella* L. which devours woolen goods; the *Tinea sarcitella* L., the commonest of all, which devours our winter garments; the *T. pellionella* L., which snips off the fur from skins and garments to make itself a comfortable shelter; and the *T. flavifrontela* Fab., the "yellow-browed" moth which is such a scourge in the collections of birds and insects in museums.

The caterpillars of all these insects live within sheaths which they carry about with them. Consequently it is sometimes very difficult to perceive them even when closely examining the stuffs which they have injured; sometimes the insect digs a sort of covered tunnel outside of which the fibers of the fur or cloth are absolutely intact, while sometimes it shelters itself within sheaths which look exactly like the stuff from which they are made.

Probably all these species of moths are capable of attacking books and in some cases it has been proved beyond a doubt that they have been actual scourges in libraries. Houlbert states that even the apple-worm is sometimes accused of belonging among these ravagers of books!

Acarians or "mites."—These minute creatures belong to the *Arachnida* or spiders. They are rarely dangerous in libraries, being in fact sometimes quite helpful, on the contrary, by destroying the insect enemies of books. However, Dr. A. Hagen reports the finding of one species, probably a *Tyroglyphus*, which might become a dangerous enemy of collections. A curious instance of a plague of the small red *Acarian*, known as the meadow-mite which occurred in New York in 1893, was reported to the Division of Entymology at Washington by Mr. F. Smith. On February 2nd of that year, these insects appeared in millions, covering the windows of houses, though at this time each individual was scarcely bigger than the point of a needle. By May 26 they had reached their full development and for a week, writes Mr. Smith, "they covered everything in sight, windows, books, furniture, carpets, sofas, etc.; they disappeared about the middle of June, leaving countless rows of white eggs in every crack and crevice of floors and walls.



WOOD SPLIT TO SHOW THE TUNNELS BORED BY THE DERMESTES OR "GIMLET" BOOK-WORM

The *Cheyletus eruditus*, a species of mite having pincher-like mandibles, sometimes called the book-mite, is not really injurious to books but is, on the contrary, useful because it destroys the *Posocidœ*.

REMEDIES PROPOSED.

Various remedies have been suggested for destroying the insect enemies of books. Best of all, according to all the authorities from Horace down, is their constant use, provided they be carefully handled.

Some librarians put their faith in pyrethrum; others sug-

CONDITION OF A PIECE OF PINE BARK INFESTED WITH A WOOD-EATING INSECT

gest mixing horse chestnut flour or even corrosive sublimate with the paste used in binding; other remedies suggested are benzine, carbon disulphide, turpentine, formol, cedar oil, and camphor. Mr. Prediger suggests rubbing the books in March, July, and September with a mixture of powdered alum and pepper on a piece of woolen cloth, whereupon Mr. O'Conor makes the following cynical comment: "This rubbing with alum is very much like the cold water treatment. It is not so much the cold water as the treatment that cures. So, it is not the alum that is important, but the rubbing. Let the librarian not confine himself to any particular month, but twice or thrice a year let him overhaul the library, dusting each separate book, not with a duster but with a cloth. Wipe rather than dust. Expensive? Very well; let a worm eat one expensive volume and then count the cost. There is no use in trying to hide a patent fact. Some shelves, even in the best managed libraries, are permitted to receive and retain a layer of dust; and where there is dust, poor ventilation, and lack of light, sooner or later the book-worm will enter in and devour. The eggs of the insects are deposited in the dust. Under favorable conditions of quiet, heat and bad air, the eggs are hatched, the book-worm is alive and hungry, and the work of ruin begins. Where will it end? When will it be discovered? Oftentimes only too late, when some great literary treasure of priceless value has been utterly ruined."

Prof. Riley advises the baking of books in some cases, care being taken to keep the temperature below a point which would injure either the leaves or the bindings.

The Psychology of Business Hours

The Necessity of Freedom from Office Distractions

By Dr. George V. N. Dearborn, M.D.

THE primary purpose of this article is to suggest, partly by supposed examples, some of the applications of modern psychological thought and practice toward the hours of business. The intent especially is to make plain certain criteria which may be useful for other business executives, for the man of "big business," for the advanced business man, so to say. These criteria are only to a less extent applicable to the "hack-workers" who are sometimes found useful even in business. The work-hours of this latter group always in large majority, must be determined more by matters of expediency and of rule, by custom, even by trade-union exactions. One of the objects of the present writing is to point out the contrast between these two groups of business persons in this respect, that the former group, the executives, may realize the better that their business-hour schedule scientifically speaking is in certain ways "out of joint." To anticipate the denouément of our little story, it needs *revision downwards* in very many cases.

Business men have said that one hears too much (among the advanced masters especially) of business-hours, of definitely set periods when the corporeal man at least must be in his particular own office more or less "private," more or less, often, a cell. Great things have been created by patient time-service in cells, it is true—but greater things outside; and more of them; and more human things. And business is eminently human, the very essence of human activity in every grade of life above the cannibal. None the less, in certain respects it needs humanizing, and its production and profits will increase as well as its popularity, when it gets this scientific quickening. In the partial humanizing of industry the executive has been forgotten; and he too often forgets himself—until it is too late.

It is part of the tendency of industrial life of all kinds in America to over-value tension, speed, *quantity* in short, and correspondingly to under-appraise quality. Yet to pure common sense quality is a higher thing than quantity (save in certain symbolic values such as money). Hours stand for quantity.

But in the direct production of the working hours of business people of the executive classes, this quality-preponderance is wholly obvious. It will readily "go" almost without any saying at all. Quality (vigor, freshness, originality, ingenuity, novelty, skill, in short), as any business man would admit, is greatly more productive than quantity usually can be. Quantity as such can be bought in unlimited amounts, but quality less easily, and very seldom indeed in your own quality for your own business. "He who would be best served must serve himself." Steady routine, arithmetical hours (unless in an exceptionally secluded and homelike or even recreative atmosphere) tend to lower the quality by depressing and efficiency lowering monotony if by nothing else. One's habits must be left partly free, thus giving to skillful initiative all its proper opportunity. This is the burden of our present experience-song as business men themselves have sung it, now and then, for many years.

For one thing, as a prominent industrial leader recently said, after dinner, many business-folk fail to look far enough ahead often enough. They tend not be over-thoughtful about themselves and the methods of their minds, and the lasting vigor of their own (and only) bodies. Even "success" is an irony and a reproach when its victim dies 10 or 15 years before his ancestral time from excessive application at the office, over-worry, under-exercise, often with over-eating added—the business "race that kills." But this epidemic of unintended suicide of Americans is not our present theme, however wise and timely this observing gentleman's remarks.

For business purposes the business man's or woman's day is divided into work-time and play-time, using the term play in this case for all expense of vital energy used not as work. The ideal of hygienic industrial science and of business alike is to make the work like play! To some readers this notion, doubtless, sounds visionary and illusory, but positively it is less so, certainly, than it now sounds. "Work" is often mistaken for drudgery, whereas in reality work propertly adapted to the worker is one of life's most dependable and persistent pleasantnesses. It is toil that hurts. As for executive, "high-grade" work, for the highest at least; such work of the most productive and important sorts can be done in play-time, not only by the subconscious aspect of the mind, but also by conscious effort, sometimes without disturbing the spirit of play and of rest. One hears it said that that business man is fortunate who has the power, especially if made habitual, of leaving his business locked up with his ledgers in his office at night.

A prominent broker of Boston is the wonder of his cronies and his neighbors in Winchester in this respect. The minute he leaves the office he is essentially a boy again and the delight of whomever he associates with. One would think he never had a business or other worry in his life. He replies in answer to compliments as to his extraordinary (apparent) youth: "I'm leading the scientific, the psychologic life—and I've the persistent will-power to put it over, that's all." Certain it is that he makes the happiest adult companion, and so the happiest home, the writer knows of. Some men and women obviously are getting, and giving, the benefits that the science of human nature is now learning to supply.

This principle of mind-control undoubtedly applies to worry, to anxiety, to one's annoyance, to every kind of apprehension; it need not apply to one's proper work, adapted to the worker. One never need be afraid, even on holiday, of properly adapted

work—but only of its more or less needless disquietudes and worry. Multitudes of business-folk have discovered these facts for themselves; and science confirms the discovery.

Even the business man may advantageously listen sometimes to the products of recent psychological research. For example, to this: The business person may well learn to leave more, perhaps much, of the solving of hard problems and the elaboration of detail, even, sometimes, to the less obvious, more internal, "subconscious" mental processes. And "the subconscious" so understood, will not worry, and has no fears, at least whenever it reaches consciousness, so that we can realize them; its real fears, as Frued has shown so dramatically, show themselves in other ways.

The subconscious aspect of mind is not a chimera as a few used to suppose. But until recently it has been the one phase of mind most neglected by psychologists, and that for reasons sufficient, but unrelated to our present discussion. If one compare the stream of mental action to a river, the subconscious part is like the mass of water, while its conscious aspect, of which alone we are continually aware, the only part we "feel," see, hear, smell, taste, etc., corresponds to the ever-flucuating surface of this on-flowing stream. So many recent books and articles everywhere have described "the subconscious" of late that scarcely more need be said as to its reality and its preëminent importance in our lives. It is necessary, however, to emphasize one thing: This subconscious or unconscious part of our minds dominates our actions to a very large extent, however little we may be aware of it. I think it is obvious that the average business man so far has not applied this psychology of the subconscious to his own needs. Psychology has just found the time to do it, in part, for him. Those who would do their own delving into the deep recesses of their minds for themselves, may well read Von Hartmann, Wm. James, Henri Poincare, Morton Prince, Schofield, Addington Bruce, R. W. Emerson. It is an absolutely interesting and even dramatic chapter in the long continued story of mind; its method is that of the best, that is most thrilling, detective stories—devious workings in the dark.

Business technique, like all others, is a development, an evolution, and as such must of necessity be forever changing and improving, or it slides back. The rules and the customs of yesteryear are today partly obsolete and outgrown. Business might well adopt the James pragmatic attitude: If it works well, it is right. The least the business person can do who wishes to make the most of passing things, is to "try out" the agreeable suggested applications of modern scientific psychology. No longer must the intelligent magazine reader, not to say reviewer, shy at the Greek spelling of the first syllable of the word psychology! Multitudes to whom "Sicology" would seem a lady worth discussing one's difficulties with deem the very same lady by the name of Pyschology too "highbrow" for mundane business affairs, office troubles included. But we are changing all that since the war, as many a business man is effectively proving.

Thus, for our present purpose, human-nature wisdom distinctly suggests that office hours often may be shortened, even on the basis that office hours are the time for making numerous decisions, for meeting others on business matters, and for doing those numberless business things that can be done only by oral conference with one's business associates. For most executives and "big-business" men and women more often than not these hours, even as they are, are needlessly long. Like the artist in literature, music, painting, sculpturing, etc., the business-executive is a creator, a person methodically using ingenuity, originality, skill, and all the other mental faculties and processes of the highest grade. As a creator he is entitled to the same freedom from time-service universally accorded the painter and the musical composer. Creation arises mostly from the subconscious associations of the brain and the mind, and these go on often best at times not measurable by the seconds-ticking clock, and in all sorts of places, even the most unlikely.

This was just about the argument put up by one of the ingenuous general managers of a great near-Boston concern recently when the family directors, somewhat old fogyish in the antiquity of their "institution," to set it mildly, actually inquired of him formally why he was so seldom in his office when called on. "You expect me to do the thinking for the business end of this company and sell it to you. I'm game for that, gentlemen," he said, "but when you expect me to do my own thinking in your own way and hours, it's a bit too thick." It is said in the works-office that he made other remarks about office boys keeping school, etc., scarcely fit for publication in a calm and sober magazine. Be that as it may, his brief lecture in modern psychology, applied, made an impression on his politic hearers and employers, for certain is it that this man now seldom can be found in his office save by appointment. And the last six months of the business suggests to passers-by that he is still thinking—and certainly where and when he pleases. Each of us has an unique thinker, and Mr. H—— had found that his creaked and squeaked and got hot under the collar and worked badly in general in the tense and formal atmosphere even of his own "private" office. This man seems to be more of a psychologist than he would have admitted had any one accused him of it.

Just as one "learns to swim out of water," so, and by the same universal process of the subconscious, the business person often can do the very most important things he has to do at all on the golf course or at home busy and happy with the wife and kiddies. Give the subconscious its opportunity by refusing to mechanize yourself! Mind is not a machine.

As quality becomes more and more important in a man's work, his business day should tend, in the long run, in general, to become shorter. The scientific basis of this principle is the difficulty of doing new and unusual things, of all new adaptations to one's environment. This greatly increased mental difficulty makes shorter hours plainly necessary for continuous efficiency if one is to go on without chronic fatigue. One has to allow also for work, especially thought work at home, etc., perhaps at night when every less thoughtful employe is sleeping. Five hours daily, exclusive of the breaks (recesses, see below) ought as a routine day for any executive to be enough; sometimes certainly even that much is unnecessary, and if unnecessary then unprofitable. The Master Subconsciousness works as well, broadly speaking, in one place as in another—as well in one's car (on the rail or on the highway) as in one's private office down town.

One of New York's busiest and most constructive theatrical producers years ago discovered that his free brain works better out of his pleasant Manhattan office than in it. In all but the busiest part of his year, mid-summer, this applying psychologist does not leave his Long Island home until ten o'clock or after, arriving at his office about eleven. He finds the most important letters of course ready for his answering, and a few admitted people awaiting him. But both of these classes of communications are disposed of by one o'clock. Then he goes to lunch at a hotel with a dozen or half a dozen managers, who spend a jolly and profitable two hours or so discussing matters of various striking sorts. Sometimes he is back in his office by three o'clock, but quite as often his afternoon "office hours" are kept on the golf links, where he practices the prolongation of life as well as golf and the plans of show-producing. Doubtless many playwrights and still more numerous actors and stars of all the leading magnitudes wish his office hours were longer, but the "efficiency engineer" can not help commending his division of his busy day. He knows "by instinct" that he can think to the best business advantage (to ignore the health factor) when he is free.

This man, whose name is an American "household word," insists to his intimates and coadjutors that more time outside (shorter business hours) for the executive generally is a means to the wider view and so a more intelligent and more generally successful "adaptation to the social environment." This is another point, then.

Shorter business hours does not mean that the hours one keeps should be less accurately, conscientiously, and systematically kept. One's business associates of course must know when you can be depended on to be in your office, even as the doctor, though perhaps less importantly, sometimes.

"Routine half-hourly breaks in business hours, however 'rushed' one is would be good psychology," says one unusually successful hustler, and goes on to explain that under usual conditions one no longer expects concentration of mind for long periods, but only concentration for strong degrees of effort for short periods; this matter is of basal importance. One's private clerk should see to it that these breaks are afforded his chief and employed by him for a change of interest and of posture, etc., for 10 minutes or so each half hour. These are good times for quick but frequent inspection of works, offices, etc., and for the gradual human acquaintance with one's employes. The tendency of these breaks is anti-snobbish as well as hygienic, and so all to the good; they make for better human understanding between labor and capital, employe and employer, which above all else psychology urges upon industry and business.

The mechanical stenographers (by phonograph) make our contention of the need of less-long and less-fixed office hours still more important than it was before they came into use. Advertisers call attention to this feature of their use, and it cannot be gainsaid. When these machines become reasonably priced, their use sooner or later is certain to be univsrsal in all but the smallest offices because of this if for no other reason. But there are other obvious reasons: one can take them along on a trip as one cannot readily take a living stenographer! And some people, more especially, can talk better to themselves than to another person; but we are concerned here chiefly with the shortening which they afford to business hours.

Pleasant emotion tires far less than unpleasant emotion of like tensity. On this account the psychologist may properly in the abstract partly deplore the adoption of mechanical stenographers.

Humor is not out of place in business hours. It is the "3 in 1" oil of life, making for happiness, efficiency, and real success. Heaven bless, indeed, the amateur humorist and good-humorist, (whatever it may be found expedient to do with the humorist by profession!) He makes the business office and its worries a place to think pleasantly of, after all; and gives to the passing office minutes, however full of dissatisfactions at times, the glamour of human nature at its best—the benign and blessed influence of joy, index of ten of the highest creative powers of which the mortal business man is capable.

It is the emotional aspect of business that fatigues, and not the "purely intellectual" processes such as planning, calculation, etc. In proportion as a business has emotion in it, for another point, then, business hours should be short. For such business folk as cannot shorten their business time to the day that is strictly ideal for the executive, it is all the more essential that business hours should be pleasant hours, or at least not unpleasant. Good humor is the superficial way of keeping high the ratio between energy-expense and enjoyment. More systematically it is a matter of variety; of "success"-atmosphere; of coaxing rather than of driving; of good mental and physical hygiene; of encouragement of all kinds. This, too, is all sound psychology, but a little outside our present theme.

Routine "four o'clock teas" in form adapted to the conditions in each case, in my opinion, are time and money and bother well expended. They help mutual acquaintance, promote the "human" element, increase the mutual respect and regard by way of association, to say nothing of the material sustenance and stimulation when these are needed most.

The time of day of hours for business for the executive is not preferably too "early" in the morning, despite Mr. Updegraff's recent examples. Morning is the meeting-time of ideas; then too the joy-efficiency ratio is highest, and the worker's energy freest. Late in the forenoon, (when the central nervous system, the brain and spinal nerve, have got into swing, and reached their momentum, and keenness of association) pure inventiveness perhaps, originality, is at its freest and best. My own observation would agree in psychologic sense with the ancient British habit of coming to business in the latter part of the forenoon. It is based on the soundest science rather than on "national sleepiness."

If one's work is such as to be within, say, four hours in office daily (and with due appreciation of modern ideas of quality and of quantity, of the stheneuphoric index, of the mechanical stenographers, etc.), the forenoon, rather than the afternoon, is the time ideal. One of the busiest and most constructive executives I know, a man who had good hygienic training (even in his "great university" course) keeps office hours most days from 9:30 until 1 P. M. He tells me that from his arrival until eleven o'clock he is doing more or less routine things; that about eleven he has "trained his subconscious" to do its most original and its best on the day's chief problems. But the real secret of this man's always amazing mental productivity seems to me to be more in his inevitable rapid walk (he lives in the semi-country) from eight until nine every morning, his usual fifteen-minute nap while spread out flat in his darkened bedroom after lunch, and his hours of sleep each night when no important social engagements prevent. He insists that while he is a working man he will work as efficiently as his intelligence and his information (respectively native to him and purchased) can show him how. He thinks he will get his "pile" early (it looks now as if he certainly would!) and then enjoy his evening-freedom all the more. His smart morning walk, his after lunch naplet, and his nine hours of sleep all combine to furnish the ideal quantity and quality of nerve-force for his habitual business inspirations late in the forenoon, led up to during his morning walk and more or less familiar scenes. He thinks much in and out of his office, but he never worries about business. He is right and broad in thinking that even business isn't worth it!—not to a real human man or woman.

One should not sit at one's business desk too long at a time, but frequently move about resting one's eyes, rearranging the distribution of blood about the body and breaking up the office hours' monotony, however strenuous. The condition of the best mental work is frequent change. No man can sit still an hour and be mentally as alert as he might be.

Fatigue comes in to reinforce this plea with its new psychology and physiology. More and more obvious to science are on one hand the abnormality and on the other the importance of fatigue in work, indeed in any human, any animal, process where true efficiency is the criterion of judgment of conditions or an end in itself. Here business has much to learn. A research made by Friedrich in 1897 showed how distinctly fatigue works on schools boys in the work of taking dictation, of being dictated to: In the morning before school began the class made 40 errors in a given piece of work; after an hour of school lessons, 70 errors; after two hours, 160, and after three hours 190 errors—a 400 per cent increase. The average business woman or man perhaps would make fewer errors and show less sign of fatigue than boys, but surely only at an extravagance of energy wholly unjustifiable when not expedient for other reasons. The moral of this simple research by Friedrich every business person should realize and use in the planning and conduct of his work.

The ideal conditions for thought (business execution of all kinds is the realest kind of thought) are not met in office hours under usual conditions. This may be noted although almost too obviously to require mention. And it is thought that counts! It is quality, and it is quantity. Perhaps, I may be permitted to repeat a paragraph from the chapter "Is Your Thinker in Order?" from my recent "*How to Learn Easily.*"

In discussing learning to think, there are six practical points to be noted: (1) a realization of the necessity and joy of thought to education and to success; (2) development of interests as varied as possible, provided they be not too

diverse and numerous at the same time; (3) an abundance of clear ideas ("concepts"), especially of relationship; (4) a habit of concentrated attention along more or less "rational" or logical lines; (5) a thought-habit developed by practice (writing, debating, reflection), and (6) the opportunity for thought, time and relative solitude).

Business, like all other things worth doing, requires more thought, more deliberate, leisurely thinking than it usually gets. It is thought that counts, but because supposedly "difficult," and therefore often not habitual, few practice it. Hence only the few, (these are the thoughtful minority) "succeed" to the utmost. Thinking is really not hard to do; it seems so to many, only because it is unfamiliar—but like swimming (and so many other pretenses) it seems "so easy to do when you know how." And clearly that so few know how to think is not the inherent fault of the individual, but of the antique, medieval, traditional educational system which still retards our civilization and the progress of so many kinds. The business executive, frankly speaking, needs to think real and ever new thoughts, thoughts new for his particular mind whether for others or not. But the average office is no place for thought, psychologically speaking—unless it may in certain cases acquire the "free" qualities of a freer environment; and this is a difficult acquirement for the average, yes, for any, business office. The practical corollary of this basal circumstance is: More time in a much freer environment, i.e., shorter business hours, for more time in the great outside. Some busy, yes very busy, "ship owners," "way down East" (as far as Portland) have made an extraordinary success of their work on this basis: They do a lot of intensive thinking, getting a great deal "thunk" as the college boys say—but office hours are to them practically non-existent.

Thought for the business person is too often not pure thought at all, but is apt to be thought-action, thought which flies off like sparks from an emery wheel in use, a by-product whether deliberate thought or not. But business problems require much "pure" thought, deliberate thought at a special time used for it alone; when one cannot only make thought of business, but business of thought!

So the business man is obliged to use time outside his set hours, however numerous; all who are real business masters know and practice this, of course. They have to do so. My present immediate plea is that the advanced business life be still further modernized and naturalized, and humanized and hygienized, mentally and phyically, by men's trusting still less to a set business day of mechanically definite hours by the clock on the wall. And that they trust their success and progress much more to the wide and versatile constructive mentality that is in each of them. Let the "thinker" work wherever and whenever it may chance to do its advanced grade of creative business. Thus will the business person be more human (i.e., more of a man or woman in a social community), and also more constructively and executively efficient—there's not a doubt of it. Some manage to get ahead certainly with a minimum of constructive deliberate thought, but with what a handicap! For emphasis sake, so that no possible reader may miss the idea, so often expressed by men of large affairs, it is repeated that in proportion as business work is routine, and mechanical, and familiar, and "hack-work," these suggested conditions do not apply; while in proportion as the work is skillful, constructive, free (planning, the devising of novelties, etc), they do apply. Our present point may be summarized in advance by reflecting that much of the more important business work of the executive and the "big-business man" requires for its thoughtful conduct an immediate environment less monotonous and freer than the average office, however complex and private, affords.

I am confident that an "applied psychologist" who tried could suggest a variety of business office, and how to build and equip it, which would meet the requirements of freedom for its users, at least, in those cases in which space and money were available in sufficient amount. The "slogan" of this office-plan would probably be: Unhurried and unworried personal opportunity! A business-thinker, untrammeled by insistent distracting actions. An environment, spiritual and physical, in which the joy-energy ratio might readily be high. Such plans would be well worth while in certain elaborate business circumstances. For the most part, however, it is more expedient and practical to have the business individual go to the thoughtful environment instead of trying to bring the ideal environment into his business establishment.

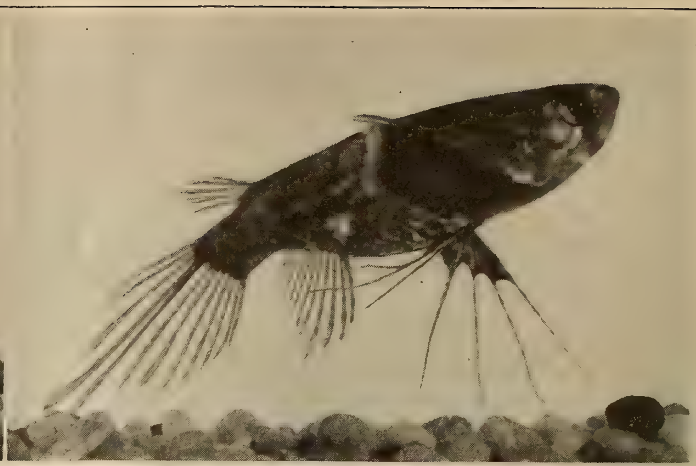
The psychology of business hours suggests one more thing. The vast majority of business folk either "hustle," or reproach themselves as inefficient if they do not "hustle." Now hustle is hurry and hurry is waste, oftentimes of material production, but always, I believe, in the life-long efficiency of the business person even considered as a machine, which a human being never is. Business hours, then, should be orderly and unhurried, and therefore unworried and efficient to the maximum, "Haste makes waste," waste usually of business production in the long run, and always of life. If one wishes to wear out early, hurried office hours are well from the hurrier's point of view. Their length has nothing to do with this; it is a matter of inner motive and feeling and of outer atmosphere.

The issue here is a clean-cut issue and cannot be denied. The busy business man (the overworked business woman has not emerged into prominence as yet) who wishes really to live as long as he can and meanwhile in decent happiness, must learn to hygienize and especially to humanize his office hours in various ways so that they will be less deadly. He must so alter his increased out-of-office hours that they shall not waste his central nervous system, his heart, his arteries and his kidneys long before their ancestral time. In the "organization" of business, few things seem more in need of reform or to be of more basal importance than keeping alive many of the best of our business-masters so that they may enjoy their "success" *longer, after* 55 *years of age.*

The feeling, or the idea even, of hurrying (*fear* lest there won't be time) is the commonest and therefore in the large the most important, occasion of worry,—and worry is the stalking pestilence of the business man snatching him early hence. A trite, a gloomy, but an insistent theme is this hurry-worry, and yet in America the most important of all that concerns the personnel of business. On general psychological principles, the normal individual, who knows better, will not continue to harm himself, and the difficult problem of all hygienic reforms becomes the befitting education of the public. In business-worry this scarcely can be the case, for every young business man nowadays inevitably must realize the dreadful and needless slaughter of business men in America, after 50, from arteriosclerosis and like effects of chronic over-strain, mental and nervous. The worry-of-hurry is the infectious agent without a doubt, and it frequently gets spread about in luxurious automobiles though never on the golf-course, or along the trout-streams of Nova Scotia. The hygienic (if not the bacteriological or medical) name of this deadly pest is certainly (or it ought to be) *Bacillus hustlecus.*

As Walter Dill Scott suggests, every business youth, on beginning his or her business life, should adopt an avocation, a fad, some outside interest, only less absorbing than his business, and should continuously cultivate it as a foil, a rest, a saving grace to his business. Provided this fad on unbusiness like interest be one not too narrow and one not too difficult and fatiguing, the recipe is fundamentally an important one for this matter of business-hours as well as for personal hygiene in general. For it will solve the danger of "unpsychological" business hours as no end of pages could but fail to do. But the ideal fads and avocations will take the business folk more and more where they can do much of their work and do it best—in God's and man's Great Out Doors. Were such a flippant mode of expression not improper in such a discussion we might well advise the over-worked executive to be often off in office hours.


THE "FLYING DART"—NURIA DANRICA


THE "WATER BUTTERFLY"—PANTODON BUCHHOLZII

The Habits and Habitats of Flying Fish

Is Their Flight Mere Volplaning?

By May Tevis

NOW that man has seen his age old dream come true of the mastery of the air he is more interested than ever in the mechanism by which flight is accomplished, not only in birds, the past masters of the art, but in other creatures which have acquired the art of sustaining themselves in the air by means of wings, fins, or the tautly stretched membranes which in some cases act like airplanes, parachutes, or the surfaces of kites.

The flight achieved by certain fishes is of peculiar interest because of the circumstance that all other creatures breathe with lungs and therefore suffer no difficulties of respiration except at unaccustomed altitudes. But fishes take in the oxygen necessary to support life through gills and these are incapable of functioning except when moist, and as a consequence they are unable to remain long out of their native element, even when able to propel themselves through the atmosphere for considerabl distances.

The fishes which have acquired the adaptation necessary for the accomplishment of this feat are found in tropical and subtropical countries in various portions of the globe. Most of them are marine animals, but three kinds inhabiting fresh waters have been discovered in comparatively recent years. Chief among the latter is the pantodon, which will be hereafter described.

Turning to the marine fishes we find that the faculty of flight exists in its most perfect condition in two widely distinct families, one of which, the Exocœtids, belongs in the group of unarmed, soft-finned fishes, called Synentognathi, while the other family, the Dactylopterids are armed fishes related to the Gurnards.

Whether marine or fresh all fishes capable of sustaining themselves in the air do so by means of an adaptation consisting of the elongation of the rays of the pectoral or breast fins and a corresponding extension of the membrane which connects the rays. The rays to some extent correspond to or are homologous with the digits of the wing of a bat or bird, and the "wing" of a fish is therefore more like that of a bat than that of a bird; the wing of the fish, however, corresponds only to the distal portion of the bat's wing—that beyond the carpel bend.

The fishes are buoyed up in the air by this greater spread of surface, which may be regarded as corresponding to the planes of a flying machines. However, the initial impulse for rising into the air is furnished by the tail fin, the muscles of the breast fins being but little more developed, if at all, than in ordinary fishes. This comparative weakness of the muscles in the breast fins furnishes a curious contrast with the very marked development of the analogous muscles in bats and birds.

THE EXOCOETOID FLYING FISHES.

The exocœtids are usually considered the true flying fish family. One of their characteristic features is the course of the lateral line, which is developed low down on each side of the abdomen and above the anal fin to the lower lobe of the caudal fin. The most perfectly adapted members of this family of fishes, constituting the sub family of exocœtines have both jaws rounded or simply angulated in front, and the pectoral fins are generally greatly enlarged and adapted to the sustentation of the body in the air. Notwithstanding this striking specialization of the group, there are considerable differences. All agree, however, but in various degrees, in provision for emergency by leaping from the water and by progress in the air.

A leading authority, aptly named Theodore Gill, has given the following admirable description of the structure of these fishes:

"The form is adapted for the life most of them lead; the subfusiform shape, with a quadrate periphery and with the sharp cut front, is fitted for progress in water as well as air with the least friction. The elongated lower lobe of the caudal enables a final strong upward impulse to be given to the leaping fish; the pectoral and ventral fins are enlarged with the maximum of surface to sustain the body in the air and the minimum of weight in the framework. Their foremost rays are also sharp edged forward so as to act as "cutairs" as well as cutwaters. The air bladder is greatly enlarged and filled with a gaseous emanation (mostly nitrogen), which diminishes the relative weight of, the body."

While most flying fishes are found in tropical and subtropical seas a few wander into temperate areas on either side of the equator. As a general rule they are found not more than one hundred to two hundred miles from land. About 65 species have been described, some 20 of which have been found in American seas. Five species are known upon the Pacific coast only and two upon the Atlantic coast, while the others enjoy a wide range—the majority of them being found both in the Atlantic and in the Pacific.

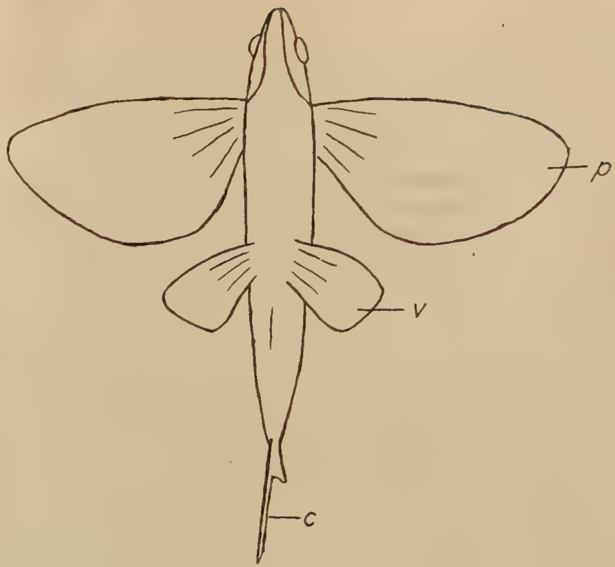
They are comparatively uniform in size, the adult fish being rarely less than 8 inches in length or more than 18. They swim in schools which are sometimes very large. They frequently swim very near the surface of the water, moving with long, sweeping strokes of the tail and latter half of the body while keeping the pectral and ventral fins pressed close to the body. Every now and then, however, the breast fin on one side is slowly stretched to its full extent, apparently, merely for exercise. A striking description of their aspect is furnished by Hugh Smith, who found this spreading of the fins "exceedingly striking and pretty, the fin looking like silver, and when several of the fish were in company the flash caused by a fin being opened, now here, now there, now on one side of a fish, and then on the other, heightened the effect considerably. It was curious to note, when the expanding fin was closed, how completely it disappeared, altering the appearance of the fish entirely." Sometimes in sport, sometimes to escape pursuing enemies, with increased vigorous movement of the tail, they spring out of the water, immediately spread their pectoral and ventral fins, and start an aerial progress known as flight.

DO FLYING FISHES REALLY FLY?

There has been much debate among naturalists as to whether the progress of flying fishes is properly to be called true flight. The answer appears to be a matter of definition. If by flight we mean the voluntary beating of the wings performed by birds and bats in the act of flight, most authorities seem to think that the fish do not really fly but merely volplane in the air. However, since modern usage applies the word flight to the motion produced in flying squirrels, flying opossums, flying lemurs, flying lizards, and flying frogs, as well as to flying planes constructed by man, in all of which cases the body is sustained in the air by expanded membranes, then we may say that the fish really fly.

Courtesy, Amer. Mus. of Nat. Hist.
THE TRUE FLYING FISH, EXOCOETUS

The question was impartially and scientifically considered by Karl Möbius, who came to the conclusion that flying fish are incapable of true flight for the simple reason that the muscles of the breast fins are not large enough to bear the weight of the body in the air. The pectoral muscles of birds which depress their wings weigh, on an average, one-sixth of the total weight of the body, the pectoral muscles of bats one-thirteenth, and the muscles of the pectoral fins of flying fish only one thirty-second. The impulse to which flying fish owe their long shooting passage through the air is delivered while they are still in the water by the powerful masses of muscle on both sides of their body, which are of much greater breadth than in the case of the herring or any other fish of their own size. According to this authority, the movement of the pectoral fins, described generally as flickering, vibrating, or flapping, is only a vibration of their elastic membrane, and is to be referred to the same laws as those which govern the flapping of a tight-set sail when a ship under a stiff breeze is driving close to the wind. Flapping or vibration at once occurs whenever the sail heads parallel to the wind.

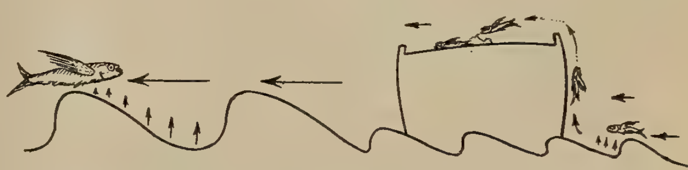


After R. Anthon
VENTRAL VIEW OF THE EXOCOETUS—*p*, PECTORAL FIN; *v*, VERTICAL FIN; *c*, CAUDAL FIN

The more rapidly a flying fish darts out of the water the greater is the momentum with which the air presses on the outspread pectoral fins. Should now the atmospheric pressure induce these fins into a horizontal position parallel to the wind their vibration is a necessary result. Let the outspread pectoral fins of a dead flying fish be held horizontally before the opening of a pair of bellows and the fins will be seen to vibrate as the current of air passes under them.

Such are the conclusions enunciated by Möbius in a special memoir (in German) on the movements of flying fish through the air (1878) as epitomized in 1885. These, however, were vigorously objected to by C. O. Whitman (1880), who urged "Admitting that in form, size, length, and structure the pectoral fins of the *Exocœtus* are less well adapted to flight than the wings of most birds, there is still ample room to believe, on anatomical and physiological grounds alone, that they are capable of executing true flight." This view is supported by Mr. J. T. Nichols, of the Department of Ichthyology of the American Museum of Natural History in New York City.

Opposed to this view are the expressed opinions of many distinguished traveler-naturalists. Moseley, who circumnavigated the globe as naturalist of the great Challenger Expedition, expressly declares that he had never seen any species of *Exocœtus* flap its wings at all during flight. Jordan and Evermann (1896), who had many opportunities for observation under most favorable conditions, were convinced that no force is acquired while the fish is in the air. "On rising from the water the movements of the tail are continued until the whole body is out of the water. While the tail is in motion, the pectorals seem to be in a state of rapid vibration, but this is apparent only, due to the resistance of the air to the motions of the animal. While the tail is in the water the ventrals are folded. When the action of the tail ceases, the pectorals and ventrals are spread and held at rest. They are not used as wings, but act rather as parachutes to hold the body in



After Theodore Gill
INFLUENCE OF WIND CURRENTS IN THE FLIGHT OF FISH

the air." Boulenger, of the London Zoölogical Garden, the best informed ichthyologist of Europe, according to Mr. Gill, voices the general verdict in the apt declaration (1904) that nearly all the family are in the habit of making great leaps out of the water, and this tendency culminates in the flying fish (*Exocœtus*), "which skip or sail through the air in a manner the explanation of which has given rise to much controversy. According to the latest evidence, the sole source of motive power is the action of the strong tail while in the water. No force is acquired while the fish is in the air. The pectorals are not used as wings, but as parachutes."

The contention that flying fishes have the power materially to modify their course in midair is generally thought by qualified ichthyologists to be not corroborated by their structure or by exact observation. Louis Agassiz (1868), however, was confident not only that they change the direction of their flight, but that they raise or lower their line of movement repeatedly without returning to the water.

They must have leverage to work from, remarks Gill, and after leaving water they must go as their final impulse directs or as the wind determines. Even those who contend that they can direct their course may admit that when in mid-flight they cannot suddenly divert their course. Mathew (1873) observed one which emerged from the sea within 10 yards of the ship and flew directly towards her, coming so violently into contact with the ship's side that it fell stunned, and floated astern on the surface of the sea with its pectoral fins rigidly expanded. Possibly they may be able sometimes to flex the tail or fold one fin in the air and thus change the course to some degree. . . .

When the fish begins to fall, the tail touches the water, when its motion again begins, and with it the apparent motion of the pectorals.

When a flying fish falls on the deck of a vessel it may spasmodically and very rapidly move its pectorals upward and downward, and such a movement may be made while the fish is "on the wing" and give the appearance of vibration so often claimed to be observed. This action doubtless adds something to the force of the leap from the water, but it is by no means actual flight, say most ichthyologists.

It has been claimed that flying fishes are not often to be seen in periods of calm and a smooth sea; it is when the winds blow strong and the waves roll high that most of them make their appearance. Hence the belief that they foretell a storm. It is easy to understand how the action of the wind combines favorably or otherwise with their flight. As any air in strong motion, when it impinges against obstacles (a ship's side or waves) rises, it raises the fish also, so that it flies over the wave or may come on board the ship. In short, as Professor Möbius proves in detail, all the phenomena observed may be fully explained by the combined action of the oblique projection forward and the wind. Directly against the wind they commonly fly farther than with the wind, or when their course found an angle with the direction of the wind form an angle together. Most *Exocœti* which fly against the wind or with the wind continue, during their whole course of flight, in the direction in which they come out of the water. Winds coming laterally upon the original course of the *Exocœti* deflect these into their direction, as shown in the accompanying diagram.

THEIR FOOD.

The food of the flying fishes consist of such animal organisms as occur in the seas which they frequent. They are numerous crustaceans some mollusks, such as Pteropods and Janthinids, and various small fishes. These fishes are, in fact, almost omnivorous, as may be understood from the means of capture used by professional fishermen and anglers.

THEIR ENEMIES.

Flying fish are practically free from capture by birds, but many of the large ocean fishes, such as dolphins, tunnies, bonitos, and albicores, as well as sharks and porpoises greedily pursue them. In order to help themselves escape, the development of the powers to leave the water has resulted, and most of the near relatives of the flying fishes which could not acquire the power have long since ceased to live, for the nearest living relatives belong to other groups—the Sauries and Half-beaks. The pursuing fishes are as swift and active in the water as the flying fishes, and even escape from the water serves often merely to delay capture for the pursuing fish may catch one as it falls from the air.

THEIR EDIBILITY.

Flying fishes are said to be unusually savory and palatable as articles of food; especially dear to epicures are the

After Brehm

A "FLOCK" OF FLYING FISH (DACTYLOPTERUS VOLITANS)

Cypselurus californicus described above and the *Cypselurus speculiger* of which we publish a photograph taken from an admirable model in the American Museum of Natural History in New York City. The latter was long known as the *Exocœtus volitans*, the later name being applied to it because of the bright silvery spots upon its flying fins which flash back the lights like bits of looking glass (Latin *speculum* = mirror). Thiss pecies is found abundantly in thei sland of Barbadoes and at certain seasons forms a staple food for the natives and is a dainty highly appreciated by chance visitors.

The bait used is putrescent fish and the tackle is very simple, consisting of a wooden hoop, 3 feet in diameter, to which is attached a shallow net with inch meshes, together with a few good lines and hooks and a set of grains. Gill quotes the following account of a fishing expedition from an unnamed writer: "As soon as the boat is hove to and her way stopped, the usual exuberant spirits and hilarious laughter are stilled

and kept under strong restraint, for a single sound will often scare away all fish in the vicinity and no more will be seen that day. The fisherman leans far over the boat's side, holding the hoop diagonally in one hand. The other hand holding one of the malodorous fish before mentioned, is dipped into the sea, and the bait squeezed into minute fragments. This answers a double purpose; it attracts the fish and the exuding oil forms a 'sleep' or glassy surface all around, through which one can see to a great depth. Presently sundry black specks appear far down; they grow larger and more numerous, and the motionless black man hanging over the gunwale scarcely breathes. As soon as a sufficient number are gathered he sweeps the net gently downward and toward the boat withal, bringing it up to the surface by drawing it up against the side. Often it will contain as many fish as a man can lift; but so quietly and swiftly is the operation performed that the school is not startled, and it very often happens that a boat is filled (that is, 7,000 or 8,000 fish) from one school. More frequently, however, the slightest noise, a passing shadow, will alarm the school; there is a flash of silvery light, and the water is clear, not a speck to be seen."

Flying fishes might be regarded as unlikely subjects for fly angling, but Francis Smith (1875) experimented with gratification to himself in this way. Off the coast of Peru a large shoal of flying fish appeared and afforded excellent sport. A variety of baits was employed in their capture—bits of red bunting, small spoon baits, and artificial minnows and flies—the most taking being a large red fly and a small gilt minnow, but all the baits mentioned caught some. In following the minnow through the water, the fish would open both pectoral fins and poise themselves for a rush at it; spreading the wings also had the effect of checking their progress if their suspicions were aroused by a near inspection of the bait. When hooked they proved a very game fish, taking out several yards of line in their first rush, and often taking a flight in the air, line and all.

The Dactylopterids, otherwise known as Flying Gurnards or Flying Gurnets, differ radically and in innumerable characters from the true Gurnards, and vastly more from the *Execœtoid* flying fishes, but a few external ones will suffice to give an idea of the family. The elongated body is somewhat swollen upward under the first dorsal, and covered with hard-keeled scales; the head is oblong and parallelpiped, and the suprascapular bones form an integral part of the skull, and extend far back as flat spiniform processes on each side of the dorsal fin; the preoperculum of each side is armed at its angle with a long horizontal spine reaching backward under the pectoral; the jaws have granular teeth; the bronchial apertures are contracted; the dorsal fins short, as is also the anal; the pectorals divided into two parts, a small anterior and a very large posterior, which spread out sideways; the ventrals imperfect and not far apart. The pectorals are set upon osseous bases (actinosts) differentiated for the two parts.

As almost every external feature is characteristic, so are many internal parts. In connection with the longitudinal arch or convexity of the back, so different from the straightness of that of the Gurnards, a very remarkable deviation of the air bladder from normal relations is noteworthy; the dorsal curvature, indeed, is a coördinate of an otherwise unexampled position of the bladder.

The air, or swimming bladder, is unique in character, as Calderwood states, in that it is not situated below, but (mostly) above, the vertebral column, not forming part of the abdominal contents, but situated dorsally in a special cavity (recess) of its own. When the abdominal cavity is opened ventrally, and the viscera removed, only the ventral surface of the bladder is seen, forming part of the dorsal boundary of the cavity. Seen from this point of view, it is formed of a broad central portion, white and tendonous, and of two lateral portions strongly muscular. The physiological significance of this comes into view when we consider one of the habits or aptitudes of the fish.

The structure and position of the air-bladder are adapted for keeping the Dactylopterid with back upward in the air in spite of the form of the body and its relations to the vertebral axis. The bladder being prevented from expanding when the pressure from the surrounding water is suddenly removed, the high dorsal position of the secondary portion becomes of the greatest possible advantage. It helps the fish to emerge from the water and maintain its equilibrium in the air.

Such are the most characteristic features of the Dactylopterids common to all the members of the family. The species are few—about half a dozen—and closely related to each other, all being strictly congeneric.

The coloring of the fish as described by Gill appears at a distance and superficially as a mixture of dark tints, but is found to contain, on closer examination, a great quantity of many-colored markings. The back is colored a beautiful brown, with dark spots and bands. The sides, as far as the middle of the belly, are pale rose, with silvery reflections, and the outspread wings show in the center rows of black and light eye-like spots, which recall the coloring of tropical butterflies by their markings and gay tints, together with the magnificent blue with which they are hemmed in. This beautiful sight may be especially enjoyed when looking at the fishes from above in the sunlight or in the broad daylight, while inducing them to unfold their wings by holding a stick close to them. Then golden green specks appear all over the body; at every motion the fins play in all colors in different places, like the wings of the butterfly known as the purple emperor, and also the gay mingling of beautifully distributed tints on the head contributes to the splendor of the brilliant creature. Besides this the *Dactylopterus* possesses the protective faculty of changing its colors to light or dark. This is particularly fortunate for the young ones, where the bottom is similarly colored, since because of their small size, they are more exposed to the attacks of the enemies. It has also been observed that the young flying gurnards far more commonly stay on the bottom of the basin than the larger fishes, and here harmonize splendidly with the sand, especially where it is mixed with multi-colored gravel. Furthermore, the coloring of such specimens is also less pronounced and the markings are darker, more monotonous, and frequently indistinct. At dusk the fishes are scarcely visible. The authorities of the Naples station have to protect the basin for these fishes with bars and nets to prevent their escaping, because otherwise the would fly through the window into the open air or to either side into the adjoining tanks. And, as a matter of fact, the station loses a rather large number of the fishes because they jump out and fall against the walls, or on the bridge over the aquarium, and perish there.

THE PANTODON OR "WATER BUTTERFLY."

The beautiful and graceful little fish called the Pantodon which has been said to resemble a water butterfly because of its delicate coloring and the graceful way it flutters above the surface of the water is found in African streams, and was long supposed to be the only example of a fresh-water flying fish. Since then, however, others have been discovered in South America and in India, the latter being the *Nuria*, also shown here.

The Pantodon has four gills and pseudo-gills. Both head and body are covered with the same sort of scales. The breast fin, which contains only a few rays, is very large and is remarkable for the fleshy prolongations which are annexed to the inner ray. This fin is almost half as long as the fish's body. The ventral fin consists of 7 rays, some of which are simple and prolonged in the form of filaments. This fin is inserted farther forward than in any other type belonging to the same sub-order, being immediately behind the breast fin. The dorsal fin is placed very far to the rear, while the tail fin is very large and pointed, having medium rays twice as long as the head of the fish. This fish has very small teeth which are extremely numerous, whence the name which is derived

from two Greek words meaning "all teeth." They are conical and are borne not only upon the jaws but by the vomer, the palatins, the ptrygoids, etc., and even by the tongue.

As we have said, the brilliant coloring of this attractive little fish makes it resemble some fluttering iridescent butterfly. It is of an olive color beneath, while the abdomen is a silvery lemon color with carmine reflections. The back sometimes is crossed with very dark transverse bands. The fins are of a bright rose color ornamented with round spots of brown shading to violet; these spots form transverse bands from the breast fin.

The Pantodon is found in the rivers of tropical Africa, the Victoria (at Kameroon), the Niger, the basin of the Congo, etc. Gill is disposed to consider the flight of this little fish as being rather a brief leap from the water. However, a more recent and apparently better informed authority, Mr. A. Ménégaux, says that in the endeavor to escape its enemy it flies just above the surface of the water for a distance of 4 or 5 meters, which sometimes extends to as much as 15 or 20, beating the water with its pectoral fins so as to form a small rectilinear furrow like the wake of a ship. It flies about 5 feet above the surface of the water except when forced up by a strong wind.

It is said to be able to live for a considerable length of time outside the water or in mud and to feed upon both plants and animals.

The Nuria danrica, or "Flying Barb," has a silvery body with a longitudinal stripe of black and above red. The fins are yellowish. The mouth has four barbels, two long and two shorter ones. The male turns red-brown at the tail during the breeding time. The female is not so slender as the male and its color is less bright. The pectoral fins are large in the case of either sex.

In the aquarium these fish should be kept in water at 20 deg. cent. When they breed the water should be about 25 deg. cent. The eggs are deposited on water plants and hatch after three or four days. The Nuria like to spawn when the sun strikes the aquarium. They eat the eggs and should be separated from them after spawning. When in danger the fish jumps flying out of the water, using the long pectoral fins.

The photographs on page 504 are taken from living specimens kept in a small aquarium on Long Island.

Carbon Monoxide a Respiration Product*

Experiments with the Floater of the Giant Pacific Coast Kelp

By Seth C. Langdon and Walter R. Gailey

In a paper presented by one of us[1] it was shown that there is present an average of 4 per cent (by volume) of free carbon monoxide in the pneumatocyst (*i. e.*, the floater) of the giant Pacific Coast kelp *Nereocystis leutkeana.*

This unique occurrence of free carbon monoxide within a living plant at once raised the question as to its origin. The intimate chemical relation of carbon monoxide to formaldehyde and formic acid had long ago suggested its possible relation to photosynthetic processes. On the basis of the physiology and structure of the plant there were grounds for the consideration that the carbon monoxide might be a product of respiration.

The possibility of its formation due to the action of enzymes or to processes of decay was the first point investigated. Finely ground kelp was allowed to undergo autolysis in contact with sea water and the gases evolved were examined. No carbon monoxide was formed, but the gas consisted almost entirely of carbon dioxide and hydrogen.

The next step was to determine how rapidly carbon monoxide was formed within the living plant. The method of work and the subsequent discussion will be made more clear if preceded by a brief description of the plant.

Fig. 1 shows the plant as it rests almost submerged in the sea water, but anchored to the rock bottom and supporting the streaming fronds from the top of the hollow gas-filled stipe. The plants vary greatly in size; individuals are often 80 to 100 feet in length and contain several liters of gas, usually at reduced pressures.[2] The inside of the gas cavity is relatively quite dry and is lined with a delicate web-like structure, known as sieve tubes. The plant will withstand a great deal of mutilation and still continue to live and grow if kept in sea water.[3]

It was found practicable to cut off the lower part of the stipe and in the upper part substitute a gas of known composition for that normally present in the pneumatocyst. The cut end was closed by a cork and the weighted plant submerged in the sea tied to a support as shown in Fig. 2. After a suitable interval changes in the composition of the gas were determined by analysis.

In the first experiments, made primarily to determine the rate of formation of carbon monoxide, air was substituted for the kelp gas. This was accomplished by filling the cut stipe with sea water and then emptying. This process, repeated 3 or 4 times, removed the small bubbles of the original kelp gas that tended to adhere to the delicate sieve tube lining of the interior. The cut end of the now air-filled stipe was corked and the prepared plant anchored near the surface of the sea as previously described.

Analyses of the gases from a series of these cut and air-

FIG. 1. GIANT KELP RESTING ALMOST SUBMERGED IN SEA WATER

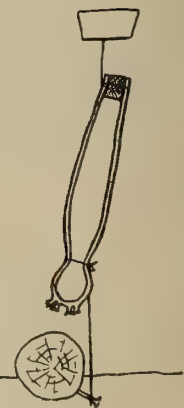


FIG. 2. FLOATER FILLED WITH A SUBSTITUTE GAS

filled plants were made after various intervals of time. The typical data given in Table 1 show clearly the gradual formation of carbon monoxide. This is accompanied by a decrease in oxygen content and the appearance of carbon dioxide. The latter is undoubtedly due to processes of decay, since carbon dioxide is not present within the normal plant. In gen-

*Reprinted from *Jour. Amer. Chem. Soc.*, March, 1920, pp. 641 to 646.
[1] Langdon, *Jour. Amer. Chem. Soc.*, 39, 149 (1917).
[2] Frye, *Puget Sound Marine Sta. Pub.*, 1, 85 (1916).
[3] Fallis, *Puget Sound Marine Sta. Pub.*, 1, 1 (1916).

eral, the cut and corked section of stipe remained sound enough to be tight for a week or ten days, although evidence of local decomposition was apparent.

The production of carbon monoxide when the stipe was filled with air was confirmed by a large number of determinations with different specimens. In most cases it appeared in quantities greater than 1 per cent. Carbon monoxide was formed by sections cut from any part of the hollow stipe if these were filled with air, corked and similarly suspended in the sea. The leaves, more properly called fronds, seemed to bear no relation to the formation of the carbon monoxide for it was produced just as readily in speciments from which the fronds had been removed.

TABLE I.

Analyses of Gases in Air-Filled Stipes.

Time, start. Hrs.	CO_2. %.	CO. %.	O_2. %.
	0.0	0.0	20.8
24	0.3	0.0	16.5
48	0.0	0.4	13.0
73	0.6	1.0	7.0
97	1.0	3.2	6.2
110	1.1	4.5	5.0

In all of the experiments detailed above, the test specimens, while anchored in the bay, were exposed to the light during the long summer day. The next step was to determine if the carbon monoxide would be formed in the dark.

For this purpose boxes were constructed which were light-tight but which would allow a ready flow of water through them. These boxes were one foot square and 18 feet long. The ends were closed by light traps, the baffle boards of which were inclined in the direction of flow of the water as shown in Fig. 3. The lids were light-tight. All holes and cracks

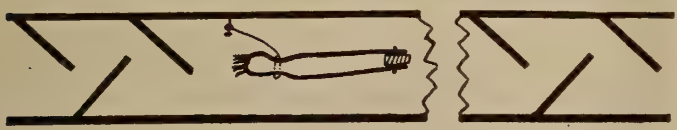


FIG. 3. STIPE ENCLOSED IN BOX TO DETERMINE WHETHER CARBON MONOXIDE WOULD FORM IN THE DARK

were closed with pitch and the whole interior was painted a dead black. The boxes were weighted so as just to float; the waves washed entirely over them except when the water was perfectly quiet. They were anchored in the bay (Friday Harbor, Wash.), where the tidal currents are heavy so that at almost all hours of the day there was a flow of water through them. They were large enough to hold several specimens without materially impeding the flow of water.

In the first experiment the top foot and a half of stipe from the kelp was filled with air by displacement, as previously described, then corked and placed in sea water in the dark boxes, the fronds being removed from half of them. After 5 days in the dark the gas was analyzed. All specimens showed carbon monoxide. The range was from 0.4 to 1.7 per cent with an average of 0.7 per cent of carbon monoxide. The 20.9 per cent of oxygen in the air with which they had been originally filled had practically disappeared and there was about 4 per cent of carbon dioxide. The oxygen was, no doubt, used by respiration and decay processes.

This data was checked by repeated similar series of experiments and it was made certain that in the dark as well as in the light carbon monoxide was formed regularly in the air-filled sections of the stipe, and that there was no relation between its appearance and the presence or absence of the fronds.

An analogous appearance of carbon dioxide and lowering of the oxygen content was shown when unmutilated plants were kept for some time in the dark. The experiment and results are as follows: Twelve whole plants were carefully collected from the same bed. Precautions were taken to avoid in any way disrupting the gas cavity. The gas from 6 of them was analyzed at once and showed an average of 15 per cent of oxygen, 3.2 per cent of carbon monoxide and no carbon dioxide, the unabsorbed residue being nitrogen. The 6 other plants were placed intact in the dark boxes and after being anchored out in the tidal currents for 6 days showed the following average gas composition: Oxygen 4.7 per cent, carbon monoxide 2.9 per cent, and carbon dioxide 0.5 per cent. There was thus a marked decrease in the oxygen content, an appearance of carbon dioxide, which is not present in the plants when freshly collected, while the carbon monoxide content was practically unaltered. These changes in the oxygen and carbon dioxide content produced by stopping photosynthetic action for a prolonged period throws interesting side-lights on the gas exchange equilibria within the living plant. The formation of the carbon dioxide on protracted standing in the dark shows that gaseous respiration products certainly do find their way into the interior cavity of the plant. Whether or not these gases bear only an incidental relation to the metabolic processes of the kelp has not been determined but should prove a fruitful field for research.

The substitution of gases other than air for those normally present was next undertaken.

As a result of more than 40 carefully executed experiments, in which nitrogen was substituted for the kelp gas, it can be confidently stated that *no carbon monoxide was formed*, either in the light or in the dark, either when the fronds were present or when they had been removed, or at any intermediate time between the initial filling with nitrogen and the 8 to 10 days that elapsed before decay had become so pronounced that observation could no longer be made. It should be remarked that carbon dioxide was formed to the extent of several per cent, even though there was no oxygen present.

Nitrogen prepared by three different methods was used. First, by heating ammonium chloride and potassium nitrite, then washing through alkali and then conc. sufuric acid. Second, from aid by absorbing the oxygen in alkaline pyrogalol. Third, the commercial product obtained from the distillation of liquid air. This last contained a little more than a half of one per cent of oxygen. The character of results was the same for the nitrogen, irrespective of the source.

Similar experiments were carried out in which hydrogen was substituted for kelp gas. The 15 determinations made showed no formation of carbon monoxide within 5 to 7 days, either in the light or in the dark. Here as in the case of the nitrogen-filled kelp several per cent (1 per cent to 9 per cent) of carbon dioxide was formed. It should be remarked that there was always a marked reduction in pressure for hydrogen filled kelp. This amounts to an absorption or an outward diffusion of the hydrogen. The whole relation of hydrogen in this connection deserves a more exhaustive study.

The hydrogen used was from two sources: first, the action of dil. sulfuric acid on the so-called arsenic-free zinc, and, second, electrolytic hydrogen.

A number of sections of kelp stipe were filled with a mixture of nitrogen and oxygen. The gas was 15.2 per cent oxygen and the remainder nitrogen. After 6 days' anchoring out in the sea water carbon monoxide had formed in all cases, the quantities ranging from 0.8 per cent to 2.1 per cent. The oxygen content had decreased and some carbon dioxide was formed just as in the case of the kelp that had been filled with air. Similar results were obtained when a mixture of hydrogen and oxygen was substituted for the gas originally present in the kelp.

The kelp withstands exposure very well and can remain hours or even days out of water and will resume normal activity when returned to the sea, that is, if not too severely sun burned or desiccated. Tightly corked air-filled sections of stipe were found to produce carbon monoxide, either in the light or in the dark, when simply exposed to the air. These

plants were still alive, although local decay soon set in. When the substituted gas was nitrogen or hydrogen no carbon monoxide was formed. It appeared only when free oxygen was within the gas cavity.

That the formation of carbon monoxide takes place only within the living plant was shown by its complete failure to be formed in the air-filled stipes of kelp that had been killed. Some of the plants were killed by immersion for 10 minutes in sea water at 50°; others by being placed in 0.02 N copper sulfate solution for 18 hours. These filled with air or other gas mixtures containing oxygen failed to produce carbon monoxide whether in the sea water or exposed dry to the air.

CONCLUSIONS.

The several per cent of free carbon monoxide which occurs in the floater of the giant *Pacific Coast kelp, Nereocystis leutkeana,* is considered to be a respiration product for the following reasons: It forms only when oxygen is present within the floater; it forms as readily in the dark as in the light; is not formed by enzyme or fermentation process when the substance of the plant undergoes autolysis and decay, and is not formed in killed plants.

The kelp, *Nereocystis leutkeana,* seemed to be remarkably well adapted to research on the gas exchange of living cells. By the use of the very refined methods of gas analysis some very interesting and valuable information might be gained as to the mechanism of plant processes. It is possible that traces of hydrogen, carbon monoxide, or other gases, not revealed by the technical analytical methods used in this work may be playing unsuspected and perhaps important rôles in plant processes.

Conditions have now arisen which make it highly improbable that either of the present authors will pursue this investigation farther, and it is with some regret that we leave this field to other workers.

This research was carried out during the summer of 1917 at the Puget Sound Marine Station, at which time the authors were associated with the University of Washington.

SUMMARY.

1. The existence of several per cent of carbon monoxide in the gas contained in the Pacific Coast kelp, *Nereocystis luetkeana,* is confirmed.

2. The substance of the kelp, when ground and allowed to undergo autolysis and decay does not form carbon monoxide by enzyme action or fermentation process.

3. Kelp plants in which the gas normally present within the floater is replaced by air, form several per cent of carbon monoxide within a few days.

4. The formation of carbon monoxide takes place only when oxygen is present as one of the gases within the floater. No carbon monoxide is formed when the floater is filled with hydrogen or nitrogen.

5. Light does not affect the rate of formation of carbon monoxide.

6. It is concluded that the carbon monoxide is formed as a product of respiration rather than as an intermediate step in photosynthesis.

SUGAR FROM PUMPKINS.

THE severely felt shortage of sugar, which is even more oppressive in Europe than in this country, has led to the revival of an ancient process of making sugar from the ordinary pumpkin. Several members of the family of *cucurbitacea* contain considerable amounts of crystallizable sugar, i.e. of saccharose instead of the glucose which is more generally found in fruits and vegetables.

The Brazilian courge is the member of the family richest in sugar since it yields a juice titrating 9 degrees in the Baumé areometer, but another species, namely, the common pumpkin of Europe and America likewise, contains a considerable amount of crystallizable sugar.

The pumpkin is easy to grow even upon ground which does not suit other vegetables. It is a sturdy plant of rapid growth and fruits plentifully even when but slightly fertilized. Its yield per acre is superior to that of the sugar beet; even with an ordinary screw-press 6 per cent of sugar can be obtained from it, while modern processes of extraction give a much higher yield.

Less care is required in the extraction of the sugar than in the case of the beet, since the pulp and the juice of the pumpkin are slower to ferment. Furthermore, the juice produces no scum when boiled and does not readily scorch. The raw sugar obtained from the pumpkin is only slightly tinted and has an agreeable flavor even before refining, in which it is superior to the sugar beet. After being refined the sugar is perfectly white, pure in taste, and fine of grain, resembling cane sugar of the best quality. The syrup of the sugar beet cannot be used for immediate consumption because of its disagreeable flavor which is bitter sweet and somewhat "weedy"; but the syrup of the pumpkin, on the contrary, is very agreeable, having a flavor which recalls that of the melon, so that it can be employed without purification.

Another advantage of the pumpkin is the value of the by-products, namely, the pulp and the seed, both of which are of use. The pulp can be kept in good condition without undergoing alteration for a considerable length of time and forms an excellent fodder for cattle, being both wholesome and nutritious, and without the strong odor of beet pulp, a feature which is very important in the feeding of milch cows.

When properly treated the seeds yield considerable quantities of edible oil, 100 kg. of seed producing 18 kg. of oil. Some authorities even estimate that this oil is capable of paying 50 per cent of the cost of cultivation.

A NEW METHOD OT TESTING THE PURITY OF FATTY ACIDS.

IT is a curious fact that when a definite fatty acid (chemically speaking) has added to it a certain amount of another fatty acid, the solubility of the first acid in the same solution is greatly increased. This phenomenon is peculiar in that the action is reciprocal and the increase of solubility is practically independent of the temperature. This phenonenon has been known for a comparatively long time, but it has been recently restudied by two German chemists, P. Waentig and G. Pescheck, in the endeavor to determine the cost of this augumentation of the solubility. The results of their experiments are given by them in the *Zeitschrift f. phys. Chemie,* for September 26, 1919. We quote the following abstract of this article from *Le Genie Civil,* Paris, for January 21, 1920.

The increase of solubility is always very great—thus the solubility of palmitic acid in carbon tetra-chloride can be increased 250 per cent by the addition of lauric acid.

The increase of solubility diminishes when the proportion of the second acid is increased—a definite limit is always reached. These peculiarities are always explained by the formation between the two fatty acids of molecular compounds which are more soluble than either of the fatty acids themselves. In the solid state there exists furthermore a similar compound formed of a molecule of each of the two fatty acids in the case cited above. This phenomenon is exhibited only when the fatty acids are not hydrolized by the sulphates, i.e., by the carbon tetra-chloride, chloroform, benzene, toluene or nitro-benzene. The phenonenon does not take place in ethyl alcohol, ether, ethyl acetate or benzoic aldehyde.

A very interesting practical application is made of this circumstance in the testing of the purity of a fatty acid. The determination of the solubility of a fatty acid is a much less complicated test, in fact, of the degree of purity of the latter than is the determination of its fusion compound. The slightest impurity and even the presence of a trace of water is sufficient to occasion a considerable variation in the solubility of the acid.

Industrial Employment of Extremely High Pressures

Production of Synthetic Ammonia

AT the session of the French Academy of Sciences on October 13, 1919, a report was made by M. Georges Claude concerning the practical use of extremely high pressures. He proved that there is but little more difficulty in exerting a pressure upon gases of 1,000 kg. per sq. cm. than one of 100 kg. We quote the following paragraphs from the *Comptes Rendus* of the French Academy.

It is a well-known fact that modern science and industry make extensive use of high pressures. Applications of this force are useful in the refrigerating industry, in the liquefaction of gases or their compression, in furnishing motor power, in the artillery, in submarine operations, and in many chemical reactions, or to solve various mechanical and physical problems. It is, therefore, of the greatest possible interest to know whether so valuable a resource is already exploited to its full possible extent, or whether, on the contrary, we may look for improvements in this line.

The artillery makes use of pressures of from 2,000 to 3,000 atmospheres and certain physical investigations, like the magnificent researches of Tammann and of Bridgman have extended such pressure to what is at present the extreme limit of 11,000 atm. But in these cases the employment of high pressure is essentially discontinuous and for infinitely short periods of time, or else the pressure exerted is in some sort static and operates upon an extremely reduced scale.

As a matter of fact most industries make use of hardly more than 20 to 30 atm.; and when the industry of compressed gases or (with Linde) that of the liquefaction of air was obliged to contemplate the production and daily utilization of large masses of gas under a pressure of from 150 to 200 atm., this was thought such an enormous increase that it was estimated that such pressures would be almost impossible to exceed. This opinion is still very generally held and it is not without interest to point out that when the "Badische Anilin" Company was obliged to explain to our commanding officers the stupendous installation of the Haber process made by them in their factory at Oppau, they did not fail to lay great stress upon the difficulties which they had been obliged to overcome, such for example, as these involved in the daily compression of large masses of hydrogen at 200 atm. I wish to establish the fact here that this idea is quite unjustified; not only is there no real difficulty in compressing gases at much higher pressures but the most ordinary common sense is sufficient to show that it is both easier as well as more advantageous to make use of a pressure of 1,000 atm., for example, than of one of 100 atm. . . . It is a well-known fact that leather collars, those useful accessories in the production of pressure, function all the better the higher the pressure is. I have been able to demonstrate that this efficacy of the leather collars of compressors is not compromised by pressures very much higher than those which it has heretofore been the custom to make use of, and their utilization which has been made feasible by a few simple precautions has enabled me to obtain by the aid of simple pistons compressors whose power, increasing progressively, has exerted a pressure of 1,000 atm. upon more than 100 cubic meters of gas per hour.

It may be observed that a compression installation with a capacity of 1,000 atm. differs from a corresponding installation with a 200 atm. capacity, merely by the addition of one or two very small cylinders, and that the law of isothermic compressions stating that the work done increases evidently merely according to the logarithms of the pressures, requires only three cylinders to compress at 1,000 atm. a substance which already required two cylinders to compress it at 100 atm.

In order to apply such pressures it may be remarked that the difficult thing is evidently not the construction in the apparatus which produce or employ them of walls sufficiently thick to safely resist such pressures. The only really difficult thing is to make the joints tight enough. But it must be remembered that no matter whether the pressure is 100 atm. or 1,000 the joints must be perfectly tight, since the smallest leak entails losses which cannot be allowed.

Furthermore it is easier to make a tight joint for 1,000 atm. than for 100, for with an equal yield of gas at a given power of installation the joint is much smaller because of the enormous reduction in the volume of the apparatus.

This opinion is entirely justified by the facts and I was able to prove to MM. D'Arsonval and Le Chatelier as early as 1917 that experimental compressing apparatus comprising numbers of joints, stop cocks, etc., can be manipulated with the greatest ease. This apparatus when charged with a 1,000 atm. and immersed in water did not allow the slightest bubble of gas to escape.

There is no doubt, therefore, that since such important advantages, thermo-dynamic and other, can be made available by very high pressures, when any given special problem requires such pressures, there should be no hesitation in having recourse to them.

USING HIGH PRESSURES IN MAKING SYNTHETIC AMMONIA.

But M. Claude was not content with demonstrating the general advantages of high pressures. In subsequent experiments he undertook to prove the value of such pressures in the synthetic manufacture of ammonia. His report upon the subject was presented by the well-known scientist M. d'Arsonval, at the session of the French Academy of Sciences held January 12, 1920. Because of the practical as well as theoretic interest of the subject we here present his remarks in full:

The German method of the direct synthesis of ammonia has proved that a pressure of 200 atm. is sufficient to insure in practice the complete combination of the gases taking part in the reaction. It may seem unreasonable, therefore, to employ a pressure of 1,000 atm. instead of 200 atm., since this increases the labor of compression, taking into account the steadily augmenting diminution of compressibility, in the approximate ratio of 3.5 to 2.3.

It is my purpose here to set forth the reasons which largely justify, however, the theoretical additional expense, but with the reservation that the practical applications required to support the theory still lie in the future.

To begin with in order to secure with a pressure of only 200 atm. the combination of 80 to 90 per cent of the reacting gases, the latter must be repeatedly passed over the catalyzer, and after each passage the ammonia formed must be separated out, since only 10 or 12 per cent of the remainder enters into combination at each passage.

With a pressure of 1,000 atm. on the contrary three passages of the gases over the catalyzer may suffice, and for a given yield the required volume of the catalyzing apparatus is reduced much more than in the inverse ratio of the two pressures, to no more than a *tenth* at most, in fact, and this circumstance of course, entails very important savings with respect to original cost, to labor, and to the expense of installation. Furthermore, by reason of the enormous increase in the factor of combination a much greater amount of heat is liberated per each kilogram of the reacting mixture, and this, too, in a much smaller volume. Because of this *auto-reaction* is secured an apparatus of very low power, and so much heat is disengaged, indeed, that it may be relied upon to furnish a good part of the motor power, in the form of superheated steam, and it should be noted particularly, since auto-reaction has hitherto been attainable only with huge apparatus combined with exchanges of very effective temperatures, that by employing super-pressures it is possible to make use of much

smaller units—and this will render it possible to utilize upon the spot the hydrogen which is a by-product of various existing industries.

In the second place the use of super-pressures renders it very easy to remove the ammonia after each partial catalysis.

I have stated that at 1,000 atm. it is easy to obtain in practice contents of ammonia equal to 25 per cent, or, when hot, a pressure equal to 25 atm. of ammonia. Since the maximum tension of this substance at 15°C. is only 7 atm. it is evident that the *mere cooling by water* of the mixture of reagents at its exit from the catalyzing tube will suffice to liquefy nearly the total amount of the ammonia—in spite of the fact that the latter is less easily condensed when contained in the mixture than when by itself, and of the circumstance that the gaseous residue (which is reduced, furthermore, to 60 per cent of the initial gas) carries with it about 2.5 per cent of the ammonia, one can thus condense after each passage more than 90 per cent of the ammonia formed.

Under the conditions established in Germany on the contrary, i.e., a pressure of 200 atm. and 6 per cent ammonia, the pressure proper to the ammonia is only 12 atm. and there can be no question of condensation by means of cold water alone, which would fail to liquefy more than half of the ammonia formed. It is necessary to do one of two things—either to reduce the entire quantity of the gaseous mixture, containing a very small amount of ammonia, to a temperature at which the tension of the latter is very low, not more than 40°C. at most, which can be done only by the aid of expensive refrigerating apparatus, or else to remove the ammonia *by dissolving it in water* injected at a pressure of 200 atm. The first process has been abandoned, having been found too costly even with exchangers having a very effective temperature, while as for the second process, aside from the very considerable labor involved in the introduction of the water, the process is very complicated because of the motors, pumps, column dissolvers, etc., it requires.

The method of employing super-pressures is free from these objections and, furthermore, it has another advantage in the circumstance that the ammonia is recovered in a liquefied form and not in an aqueous solution.

I have already explained elsewhere (vide the *Comptes Rendus* of the French Academy of Sciences, Vol. 168, 1919, p. 1101) how the rational transformation of ammonia into fertilizer ought to be effected not by means of the costly sulphuric acid but by the aid of the chlorine which is at present lost as a by-product in the Solvay soda industry. By this means, too, enormous quantities of sodium carbonate are obtained as a sort of by-product. A closer study of this question has led to an adaptation of the Schreib process in which the expensive evaporation of large masses of solutions is replaced by *alternate precipitations* of CO_3NaH and NH_4Cl, the latter being rendered possible . . . by the insolubility of the NH_4Cl in the *neutral* solutions of ammonium carbonate, at an approximate temperature of 5°C. This process, which avoids, furthermore, the loss of large quantities of non-decomposed sea salt which is thrown down at the same time as the $CaCl_2$ in the present Solvay process, requires, therefore, a large amount of *cold*. This cold is produced directly by the mere evaporation of the liquid ammonia and in amounts which are almost sufficient in themselves by reason of the 300 frigories per kilogram, whereas synthesis with a pressure of only 200 atm. must obtain all this cold, other things being equal, by a very considerable extra expenditure of energy. The liquid form in which the ammonia is obtained by means of the super-pressure process saves, therefore, a large portion of the excess energy expended in this process.

It should be remarked, moreover, that the principle of the alternate precipitations of NH_4Cl and of CO_3NaH in the same liquid requires that the *ammonia* should be delivered *in the gaseous form*, as well as the carbon dioxide. Hence the ammoniacal solution obtained in the German process, which must be distilled in order to vaporize and rectify the ammonia, necessitates expenditure of heat, a complication from which the super-pressure process is free.

Finally, I will point out another important difference. In the German process as I have said, above, the low factor of combination makes it necessary to repeat the passage of the gases over the catalyzer a great many times; in order to do this it is necessary to raise the pressure of the gases which have traversed the system by an amount equal to the loss of pressure which they have undergone, in other words, by from 10 to 20 atm. Since these passages of the mixture of gases over the catalyzer are very numerous the corresponding expenditure of energy amounts to more than one-tenth of the initial energy of compression, and the pumps required for the recompression constitute a fresh complication. These two inconveniences are avoided in the super-pressure process because of the greater magnitude of the factor of combination, the facility with which the ammonia is abstracted, and the possibility of attaining an auto-reaction with a very slight gaseous expenditure, it is only necessary in this process to cause the gas to traverse a very small number of catalyzing apparatus *successively*, abstracting the ammonia after the passage through each, which is obviously quite possible without any raising of the pressure; furthermore, this process permits the continuous elimination of inert gases such as argon.

If we attempt to calculate all the ways of economizing energy made possible by this new process, we find that it is not only superior in all probability as respects the cost of installation as well as in its simplicity and the possibility of employing small units, but also, perhaps, as regards the special consumption of energy.

RÔLE OF ZINC IN THE HUMAN BODY.

RECENT researches made by Prof. Delezenne at the Pasteur Institute in Paris set forth the important part which is played by zinc in the functions of the human organism. The question was brought up in the first place by a series of researches upon the venom of serpents, this work being still going on with fruitful results, but in the meantime he was led to observe that zinc occupies a place of the first importaace in the animal economy, and especially as concerns the cells which constitute the same. In the first place he found that contrary to what was believed hitherto, the metal zinc is an essential and permanent constituent of the substance of tissues and organs, and in fact this metal exists in all organs, although in a rather small percentage, or about 0.0001 by weight, which is variable according to the character of the organs. The highest proportion is found in the nervous centers, for instance the brain or the tymus. As to what was the special rôle or the proper function of the metal in the working of the organs of the body, he was led to seek the solution by referring to his researches on the venomous substances of serpents, for these had shown him that zinc always existed in a considerable proportion, up to 0.6 per cent, in the venomous substances, and what is remarkable is that these poisonous substances are usually more active as they contain a greater amount of the metal in their composition. It is also found that the properties which are peculiar to zinc are connected with the special form of the chemical combination which contains the zinc in the venomous substances. This is analogous to what is observed for instance in the case of potassium, which is toxic in cyanide of potassium and non-toxic in the chloride and other salts of this metal. In any case, it appears to be demonstrated that the property possessed by the animal poisons of decomposing the cells or of partially decomposing the nucleic acids which are the fundamental constituents of the cells, is connected with the presence of zinc. Then when it is remembered that the metabolism of the cells, or the totality of the chemical operations of nutrition, is also connected with the transformation of the nucleic acids, it is to be concluded that zinc is very probably one of the most essential agents in the growth of the human body.

THE "BEAMING" PROCESS, WHICH CONSISTS OF SCRAPING HAIR OFF THE SKINS

REMOVING HAIR BY MACHINE AFTER THE SKINS HAVE COME FROM THE SWEATING VAULTS

Leather—A Product That Is Still a Mystery

Process of Tanning Hides

By Robert G. Skerrett

Photographs copyrighted by Keystone View Company

IF all steel looked alike to the bridge builder we should have catastrophes in plenty. And just because all leather is simply leather to the vast run of shoemakers the public pays not only dearly for its footwear but suffers physically, yes mortally, therefor. But don't let us anticipate. We shall come to the evil of this attitude in time. In the meanwhile let us try to describe an industrial paradox.

The dictionary tells us that leather is the skin of an animal, or some part of such skin, tanned, tawed, or otherwise dressed for use. And recourse to a whole library of lexicons is unlikely to prove more definitely revealing. In fact, we have it on most excellent authority that leather is leather; and exactly why this is so still has the scientific world guessing. True, the chemist is alive to the fact that tannin works the unexplained transformation; but what tannin is persists in remaining pretty much of a mystery, although the technicists know where to get it and can certainly identify its presence by reactions induced when associated with salt and gelatin.

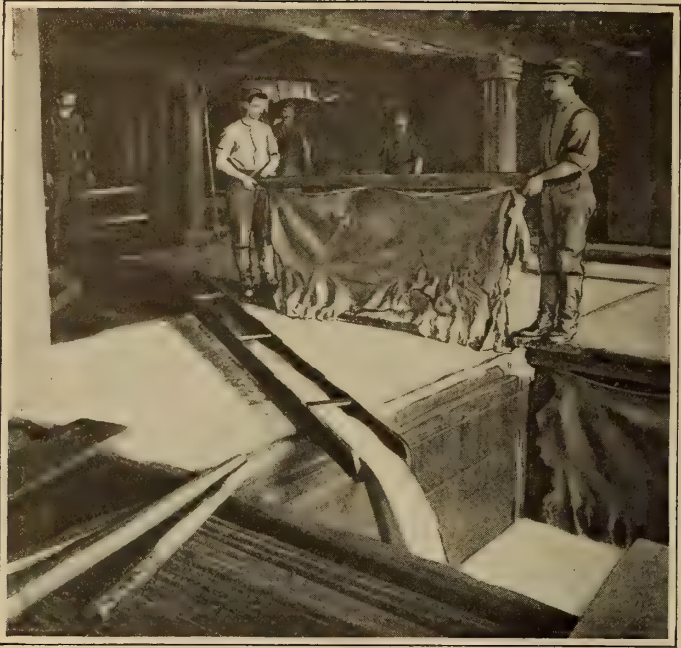
It will probably surprise no one to be told that the latest theory having to do with the art of tanning is that the change wrought in the skin is due to an electrical attraction set up between the hide fiber and the tanning liquid, because year by year we are discovering more and more of electricity's manifold activities in this mundane existence of ours. Professor Henry R. Procter, of the University of Leeds, England, is now confident that the complex substance commonly known as leather is the product of the co-precipitation of hide and tannin resulting from the electrical phenomenon just described. Eventually, this pronouncement may have its helpful effect upon an industry which is undeniably of a groping character today.

The general public has every reason to be interested in the broad topic of the making of leather, because the matter eventually touches everyone's purse and, in a large measure, his pride, as well. Indeed, it is probably no exaggeration to say that the health of millions hinges upon the character of the material worked into their common footwear. Without going into technicalities, it will answer our purpose to know that the skins of vertebrate creatures—mammals, for instance—are composed of four layers or membranes. The outer one consists of the epidermis, which carries the hair; the second one contains the nerves, the smaller blood vessels, etc.; the third, or middle portion, is the dermis or true skin made up of fibers interwoven and intersecting in every direction, and the fourth, or innermost, is the fat-bearing tissue immediately overlying the flesh. It is the true skin or dermis which forms the basis for leather.

The tanner seeks primarily to fit the skin for leather making by getting rid of the hair and those portions of the skin that are liable to putrefaction; and with these ends achieved he has left the fibrous texture or layer which is transformed by tanning into the material used in the manufacture of boots and shoes, bags, harness, belting, gloves, etc. The nature of the ultimate product depending, of course, upon the kind of hide or skin utilized and the processes employed during its treatment at the tannery.

Here in the United States we use the hides of horses, steers, cows, calves, pigs, goats and sheep, not to mention such imported materials as the hides of the buffalo and the llama. In some parts of the world, from which we get "stock" for tanning, the hides are simply air dried in the sun, while sheep skins are shipped to us from Australia and New Zealand after they have been pickled by means of a salt solution to which sulphuric acid has been added. Hides of native origin, however, are generally preserved for the time being by salting, and reach the tanner in a damp condition, carrying all of the salt they will absorb. Because of this fact the tanner knows just what he is getting when he buys the hides by weight; and this is the usual practice.

No matter what may be the kind of leather into which hides are to be worked by subsequent tanning, all of them have to be soaked to soften them as a preparatory process. For this purpose clean and soft water is desired; and if the water be hard it is made soft by a suitable amount of borax. The


VATS USED IN THE TANNING OF HIDES


OILING HIDES TO PRODUCE FLEXIBILITY

soaking also serves to remove salt, dirt and blood adhering to the hides. Care has to be taken that the hides while thus being softened do not become flaccid. If soaked too long, the hides lose gelatin and make loose or spongy leather. The soaking is in two stages each of twenty-four hours. Lack of caution during the soaking may produce a "pricked and pitted" grain—"grain" being the natural outer surface texture of the leather. Hides that have been dried have to be milled or worked after soaking in order to assure a satisfactory limpness so that they will later on permit the tanning liquor thoroughly to penetrate the fibrous mass. In a dry hide the intermingled fibers are closely cemented together, and the aim is to break down this bond in tanning without injuring the network upon which the final flexibility of the leather depends.

Following their soaking, the hides are subjected to liming by being placed in vats filled with a solution of slacked lime. To this bath is added a percentage of sulphide of sodium. There are six of these successive liming periods, each of twenty-four hours' duration—the hides being taken out of the preceding bath before being put into the next one which differs somewhat in strength and composition. According to the character of the raw product, the liming operations take anywhere from three to ten days. After passing through the last vat, the hides are reeled into warm water, where they remain two or three hours. The immediate effect of the lime is to swell the fibers of the skin and thus to split them up into their constituent fibrils.

Because the upper layer of skin has been dissolved or loosened by the lime the hair can be readily removed by placing the hides upon "beams" or slightly rounded slanting boards and scraping the exposed surface by means of a dull metal instrument.


PLACING HIDES IN THE OILING DRUM

The choicest grades of hair are later on sold to plasterers, and the white hair is not infrequently used in the manufacture of so-called all-wool cloths. Having disposed of the objectionable hair—and it is essential to get rid of all of this if the leather is to be finished on the grain—then the next step is that of deliming. This may be preceded, however, by splitting the hides or cutting them into "sides." Deliming is accomplished in two ways—by an acid bath or by recourse to bacterial bathing—the latter being done by animal manure. Artificial baths are widely employed at the present time, and these are composed in the main of ammonium chloride and pancreas. Bran drenching is another way of neutralizing the lime, and all of these processes tend to make the hide pliable. The extent to which the treatment is carried is contingent upon the kind of leather which is to be produced.

Once more the hides must be washed thoroughly with clean warm water. This is very essential to insure a good clear grain which will color evenly. It is then customary to put the hides over horses to drain, and it is not unusual to subject them to pressure to free them of some of the remaining water before starting the actual tanning. Tannin for this purpose comes from many sources, but most of these are of a vegetable nature.* Their net effect is to separate the hide fibers, hold them so, and to make the animal material nonputrescible. Years ago hemlock and oak barks furnished much of our needed tannin, and the leathers so obtained were known, respectively, as hemlock and oak leathers. When the leather was the outcome of tanning successively with oak and hemlock liquors the product was termed by the trade "union" leather. Today, union leather

*See article on Synthetic Tannins in SCIENTIFIC AMERICAN MONTHLY, April 1920, pp. 326-330.

is the result of treatment with any kind of tannin that can be had in the market. Tannin from chestnut bark is now employed extensively in turning out heavy leathers; and largely because of the war and the need to make ourselves as self-sufficient as possible in raw materials, it has been found practicable to secure an excellent tannin from the bark of both the white and the black spruce. For the lighter leathers the leaves of the sumac, which contain between 20 and 30 per cent of tannin, are a source of supply.

THE PROCESS OF IRONING THE LEATHER

Without going into details, the tanning procedure consists in putting the hides, stage by stage, in tanning liquors of increasing strength and agitating the hides the while by moving them in one direction while the liquid bath travels oppositely. Gradually the solution penetrates the hide—sole leather, naturally, taking longer to accomplish this than the lighter materials. By carrying the tanning process to the point of complete penetration the resulting sole leather, for example, is a firm and heavy product. In the days gone, it took quite two years to convert the "green" hide into marketable leather, but now the tanner thinks he is doing quite enough if he devote five months in reaching this stage.

This is not hard to understand, as an expert has explained it, if we bear in mind that hides bring quite twenty cents a pound wet salted, and a sizable tannery puts in treatment anywhere from 10,000 to 50,000 pounds every twenty-four hours. Because of the capital thus invested the tanner is anxious to realize on his investment as soon as possible, and this economic side of the industry has its reflex in the grade and the wearing quality of the leather worked into our shoes. This effort to speed up is evidenced in what is known as the drum-tannage method. By that process hides are placed in a revolving drum carrying a comparatively small quantity of the tanning liquor, and this is strengthened rapidly as the hides are agitated. It is said that tanning can be accomplished in this way in a week's time; and the resulting leather is very satisfactory so far as appearances are concerned. The material, however, does not show up well in service in the matter of keeping out water. The reason for this is that the tanning liquor has not time enough in which to fill the hide substance with the insoluble matter, technically termed "blooms," which, in the more leisurely prepared leathers serves to hold the water at bay. Shoes made from drum leather are essentially for dry-weather wear. The only trouble is the buyer seldom, if ever, knows this.

When sole leather has been duly tanned it is customary to subject it to a filling process which is called in the trade "fat liquoring." As may be readily understood, this liquor is composed of oils, grease, and soaps of one kind or another. The fat liquor, with the leather, is placed in a heated drum, and the latter is revolved for the better part of three-quarters of an hour, during which time the leather absorbs the oleaginous mixture and the while gets rid of any water that may have been stored in its substance. The leather is next removed from the drum, placed on horses, and allowed to drain

BLACKING THE LEATHER AND PUTTING ON THE FINISHING TOUCHES

for twenty-four hours. Following this the hides are "struck out," i.e., stretched on each side with a tool, oiled on the grain, and then hung up to dry. During drying the temperature should be at about 80 degrees Fahrenheit; and it is necessary to insure a good circulation of air so that the leather will not dry too rapidly and thus acquire a parched appearance.

Where leather is tanned by the chrome process, which is used in this country in the making of about 90 per cent of the material employed in the manufacture of uppers for men's shoes, the tanning liquor is composed of a solution of basic sulphate or chloride of chromium. The salts thus entering the hide cling fast to the fiber and will subsequently resist washing with water—the leather will even stand boiling. Chrome leather while not as good as that produced by the use of vegetable tannins is, nevertheless, of excellent quality when care is taken in the selection of the material and due heed is exercised during the processing.

A combination of regular tannage and chrome tannage—either preceding or following the other—yields a leather of a high grade which will have the wearing qualities of chrome leather but will not slip on a wet pavement like the latter. This leather retains its flexibility and is strongly resistant to water. This double treatment requires that each tannage shall penetrate the leather through and through. The reason why more hides are not so dealt with is because of the much higher costs involved. When leathers needing coloring have been duly dyed and, possibly greased, they are permitted to dry to a suitable degree and are finally surfaced by means of rollers, frequently made of glass, operating upon a pendulum-like arm, which impart a polish.

Curiously, the shoe manufacturer does not concern himself about the possible adulterations which go into the tanning processes. He seldom, if ever, analyzes sole leather, for example, to discover if there is any undesirable matter stored away in the product. The one thing that he is fussy about is that the leather shall have the desired color—something that in no wise indicates the wearing or other essential physical qualities of the substance. The net result of this attitude is that the manufacturer of shoes is principally bent upon appealing to the eye of the retailer and the ultimate consumer; and the latter is generally unable to safeguard himself against deficient quality. He does not even realize what the manufacturer's indifference means when his shoes wear out quickly; the more money he spends in footwear the more the industry profits.

It is an established fact that the modern art of tanning falls a long way short of the standards set when the relatively primitive methods of making leather prevailed. Books bound a hundred years and more ago with leather of those days are still in good condition, while modern bindings of leather are very apt to go to pieces after a score or so of years. The urge of haste has not yet been offset by anything that the chemist has been able to evolve for the purpose of speeding up the transformation that takes place in the hide in turning the material into leather. Indeed, the outstanding shortcoming of the art is a fairly general absence of positive standards by which the several processes can be gaged and their respective products graded.

In a very able paper read before the American Chemical Society by Dr. Lloyd Balderston, that eminent expert laid a great deal of stress upon this aspect of the subject of the treatment and manufacture of leather. And at that time Dr. Balderston said, in effect, that it was the hope of Professor Procter and his co-workers at Leeds, by establishing the electro-chemical nature of tannins, to make it possible thus to foretell the character of leathers to be obtained from different materials and mixtures.

America is not only the greatest shoe-manufacturing nation, but our people utilize in other ways enormous amounts of leather. The tanning industry, therefore, is one of our biggest and most important activities. In normal times we amplify our own raw supplies by importing anywhere from 600,000,000 to something like 800,000,000 pounds of hides, and it is self-evident that the question of properly converting this material into really satisfactory leather is a matter of the utmost economic moment. The problem of the chemist is now to find processes by which the hide can be transformed in the shortest practicable time into leathers possessing all of the endurance and other desirable qualities which used to characterize the output of the tanneries of decades gone. The chemist will undoubtedly be able to open the path to this goal when he determines beyond peradventure just what leather really is.

Something About Artificial Silk*

Present Production and Possible Sources of Future Supply

PERHAPS no other textile fiber at the present time absorbs so much attention of the financial and the industrial world as artificial silk.

Financiers, both here and abroad, are busy with the shares of the existing and prospective countries manufacturing artificial silk under various trade or descriptive names and according to the several processes already known as successful, and high hopes are entertained for the future of artificial silk, which for some time past has been established as a staple product. On the industrial side optimism is also the predominating view of the situation, by reason of the almost daily increasing number of articles in which artificial silk is associated, and by reason of the insufficiency of the supply of natural silk to meet the requirements of the consumers and the manufacturers. Also because fabric manufacturers have obtained with artificial silk, used in connection with natural fibers, effects and fabrics not possible even by the use of natural silk. One such effect is high luster, and the other is a "hand" that no other material but the artificial fiber can impart to the goods. And by the same token, the fiber gives an apparent added value to the finished material more through its appeal to the lust of the eye than from intrinsic worth.

This is not so paradoxical as it might at first seem since the high cost of artificial silk in itself contributes to meeting the luxurious demands of the present uncertain period. It has now secured a very important position in the textile industries, in no branch of which does it occupy so much a position of importance as it holds in the silk industry. It may, therefore, not be out of place to refer here to some of the unfamiliar history of this product.

The name artificial silk first appeared in patent literature in 1855, when Audemars, of Lausanne, described a method of preparing vegetable fiber solely for the purpose of use in incandescent lamps. In 1844 Count Chardonnet prepared a fiber from collodion which was expected to compete with natural silk. It was, however, not until 1895 that he was able to offer a denitrated fiber. In 1900 the Fremery and Urban patent for the production of cupro-ammonia collodion was exploited, and in 1903 there came into evidence a novelty which represented the last word in the industry of making artificial silk. The Cross and Bevan patent, taken out in England in 1892, and in France in 1893, concerned the means

*From *American Silk Journal*, April, 1920.

of preparing a thick viscous liquid, called viscose, intended for the purpose of brightening fabrics, which was subsequently so perfected that it was possible to spin yarns from the viscous liquid, and quite a large industry has been built on it since then, so large that extensive plants operating on this system have long been established in many of the European countries and in the United States, and is today practically in control as the world's largest distributers of viscose.

Up to 1903 the new industry, interesting though it was, was not seriously regarded in the industrial world, but was rather considered in the light of an interesting novelty. In that year, however, the Société de la Viscose put on the market the artificial silk which until recently has been the last word in artificial textiles. It may here be noted that this company is, in fact, the monopoly and controls both the European and American markets very effectively, selling or withholding its goods as it sees fit; and only now has the widespread demand for chemical textiles encouraged lesser companies to undertake the manufacture of artificial silks.

As the raw material for the production of viscose is wood, the industry is one which can be established in any climate. Indeed, today the industry, operating in one process or another, is established in the United States, Belgium, Switzerland, Hungary, Poland, Italy, Germany, Russia, England and Japan. In Germany alone, it is estimated that the production of artificial silk was, just before the war, 5,000 kilos daily, and in France, 4,000 kilos.

It is very apparent, however, that the increase in favor of the vegetable fiber coincides definitely with the increase that has taken place in the production of natural silk. In 1914, 19,000,000 kg. of natural silk was produced; in 1906, 23,000,000 kg.; in 1912, 27,000,000; in 1914, 22,000,000; and in 1918, approximately 25,000,000 kg. Yet, for some time past, and at present, there is always a scarcity of silks on the markets, and when it can be got, prices are high, which are features which go to prove most definitely that natural silks are sought after more than ever. That indicates the probability of the belief that natural silk has nothing really to fear from artificial silk as a competitor.

At Lyon, a renewed impetus was recently given to the use of chemical textiles by the invention of an entirely new process, the product of which is called silk cellulose. This new form of cloth is claimed to possess a brilliancy comparable to silk schappe, a remarkable solidity and durability, a touch similar to silk, and absolute imperviousness to water; at the same time it is no more endangered by fire than the ordinary natural silks. While the thread of the viscose silks is, of necessity, relatively coarse and thick, the new silk permits of making threads of considerable fineness, and is particularly remarkable for the quality of the velvets which can be made from it. The new process differs radically from the old processes. Instead of converting a thick liquid (the viscose) into thread, it appears that it is possible to preserve the wood fibers and convert them into a brilliant and solid cellulose. As a result of this, there is obtained a greater molecular concentration and a regular geometric form in the elements that make up the thread; all of which, it is claimed, greatly increases the strength and durability of the cloth.

A large factory for the production of the new textile is being projected for large-scale commercial production in the Lyon district, where such materials as velvets, jerseys, satins, draperies, linings, and other silk goods will be woven. It is as yet quite impossible to state, with any exactness, the price at which the silk cellulose will appear on the market. Although artificial silks can already be obtained at very advantageous prices as compared to natural silk, the inventor of the new process claims that his product will be able to cut still further the cost of chemically produced threads.

Despite the fact that for years to come the artificial textile may not compete with natural silk, yet the producers of the latter must eventually look for advances and inventions on the part of chemists that may ultimately remove the defects now so obvious in the viscose silks. What is most needed is ability to spin a much finer thread, which is at present extremely difficult to do on account of the air which is held in the coagulating bath in which the artificial threads are formed. In seven or eight years, when there has been time for a surplus of artificial silk to accumulate on the market, due to the establishment of new plants and increased production of other textiles, those whose interests are bound up in the artificial silk industry will be forced to bring about new developments in order to enable it to hold its place; at that time real competition may be looked for between natural and artificial silks.

The French weavers of vegetable thread, because of the difficulty they experience in obtaining sufficient quantities of that kind of thread, motivated, not long ago, a demand for the reduction of the import duty on that maerial, which is now 15 francs ($2.895) and up per kg. (2.2 pounds), including the recent increases. The lowering of the duty was, however, considered hardly justified, it being taken into consideration that at the last meeting of the Belgian Tubize Silk Association it was announced that America would absorb 20,000 kg. (44,080 pounds) per day, if that amount could be produced, in spite of the entry duty of 35 per cent ad valorem. The prevailing opinion is that the barrier of fifteen francs does not appear to be of a nature to hinder importation into France at the present time, in view of the fact that the French production must be stretched to its greatest extent in order to satisfy the needs of the home market, which is turning a deaf ear to sales orders from abroad.

From the foregoing it will be seen that whereas not so many years ago artificial silk was tabooed in the silk trade, it has since found a position of its own in the industry, and its wonderful success today shows there is ample room for both fibers, and now, instead of the name "artificial silk" being an appellation damaging to the interests of the silk industry, it really serves the purpose, by contrast, of eulogizing the many intrinsic merits of natural silk.

THE LENGTH OF WOOD FIBERS.

The current supposition that each species of wood has a characteristic fiber length is not borne out by the many thousand measurements which have been made at the Forest Products Laboratory on wood fibers. These measurements show that a greater difference may be found in one tree than exists between the average fiber lengths of different species. In one Douglas fir disk, for example, the fibers varied from .8 to 7.65 millimeters (.03 to .3 inches) in length, which is a variation of nearly 7 millimeters. On the other hand, the averages of several thousand measurements on Douglas fir and longleaf pine were less than one millimeter apart, being 4.41 and 3.67 millimeters, respectively.

In the first case, 67 per cent of the fiber measurements in one tree fell between 4.5 and 6.5 millimeters, which roughly indicates the meaning of the common term "average fiber length" for the tree or species.

Such data obviously can be of little value for identification purposes, because of the overlapping of the ranges of fiber length in the various species.

Some relations have been observed between the length of fibers and their position in the tree. During the first 20-50 years of growth, the increase in fiber length from the center of a tree outward in any plane is very striking. An approximate maximum having been attained, fiber length, though it may fluctuate somewhat, does not radically change thereafter, even in trees 400 or more years old. Some increase in fiber length occurs also for about two-thirds of the distance from the butt to the top. Within each annual ring the length of the fibers varies, particularly in the conifers, where the early springwood has the longest elements, and the last formed cells of summerwood the shortest in the ring.

No clearly defined relation has been found between fiber length and the strength of wood. The longer fibers are often found in the weaker material.

Looking Through the Phonograph Record

Elements That Produce Surface Noise

By Francis F. Lucas

SOME years ago, when the phonograph was in its earlier stages of development, vaudeville performers often entertained their audiences with imitations of phonographic reproduction. All of the then characteristic tinny sounds with the usual accompaniment of scratching and snapping were more or less realistically imitated and the performances were quite apt to end with the repetition of a few sounds, indicative of the stylus traveling round and round in the same groove. In those days the phonograph was more of a novelty than it was a musical instrument, but the tremendous development which followed has made it one of the most popular of musical instruments.

As an entertainer it probably has no equal and has been the means of bringing music and entertainment to the most remote places. During the war we read of the sub-sea raiders lying quietly on the ocean bed while their crews listened to the latest in popular music on the phonograph. All of which goes to show that some really remarkable improvements must have been made, otherwise the demand for phonographs would have died out with the novelty. With the incentive of popular demand it is reasonable to expect that the development of the future will result in more faithful reproduction and greater clarity of tone with the elimination of all extraneous noises.

Recently a laboratory study of the standard phonograph records was undertaken with the object of comparing the different record surfaces so that the structural elements producing surface noise might be made more tangible and perhaps, thereby, facilitate the application of corrective measures.

Surface noise or "scratching" of phonograph records is one of the peculiar characteristics of phonographic reproduction which, no doubt, everyone would like to see done away with. It results from contact of stylus and record and has several contributing causes, one of which is the character of the record surface.

To the unaided eye the surface of a record appears exceptionally smooth and highly polished but when played all records produce surface noise. If one were analytically inclined he probably would conclude that even though the record surface does appear smooth and polished it must have miniature hills and dales and be more or less granular. Even with the aid of a microscope and using methods which are usually applied when examining opaque objects the results are not satisfactory.

For the benefit of those who have not had actual experience in technical microscopy it may not be amiss to say that the mounting of objects for microscopic examination is somewhat of an art in itself and that the mode of procedure differs with the character of the specimen. In some cases the specimen is mounted as an opaque object and oftentimes its surface is etched with some reagent which will differentiate in the structure. In other cases very thin and transparent sections of the object are mounted in a suitable medium on a glass slide and protected above by a thin piece of glass called a cover glass.

For critical examination of a phonograph record by microscopic methods the conditions seemed to call for a very thin section from the record surface, a section of the skin so thin that it could be examined under considerable magnification by transmitted light. In making the section the surface of the record should not be disturbed even to the slightest extent, otherwise the true conditions would not be disclosed by the

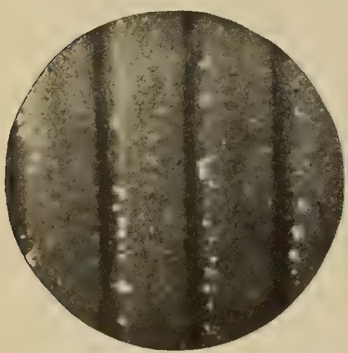
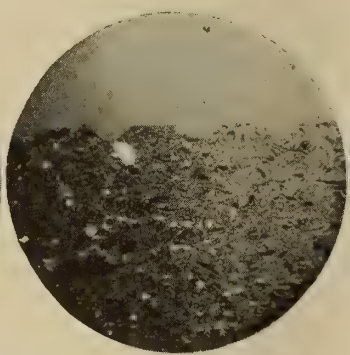



FIG. 1 RECORD A FIG. 2
37 DIAMETERS

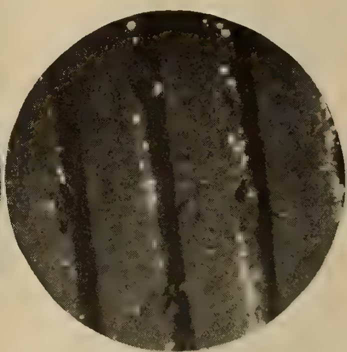
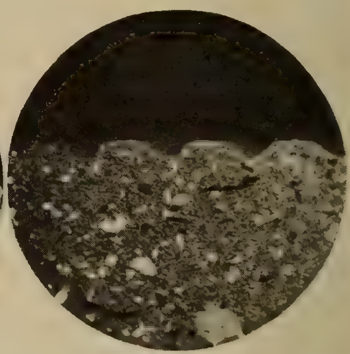



FIG. 3 RECORD B FIG. 4
37 DIAMETERS

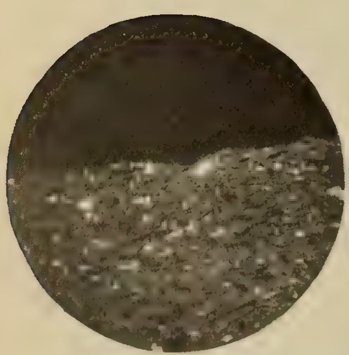
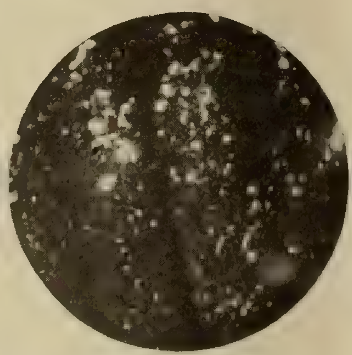



FIG. 5 RECORD C FIG. 6
37 DIAMETERS

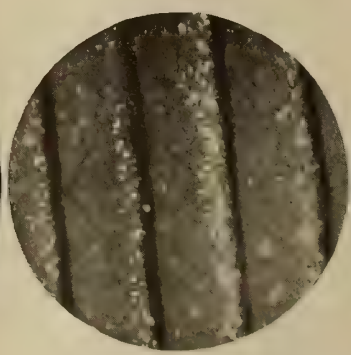
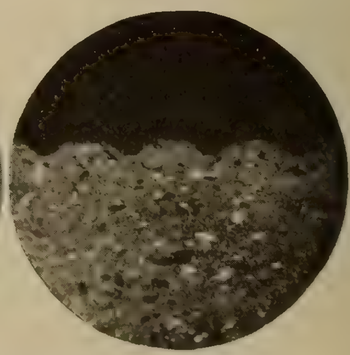



FIG. 7 RECORD D FIG. 8
37 DIAMETERS

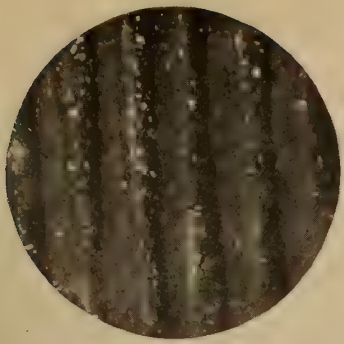


FIG. 9

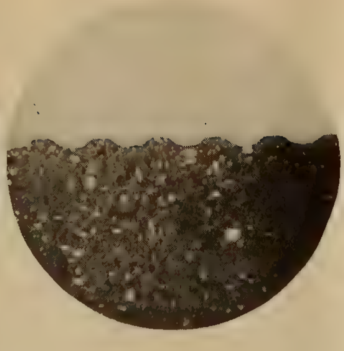


FIG. 10

RECORD E
37 DIAMETERS

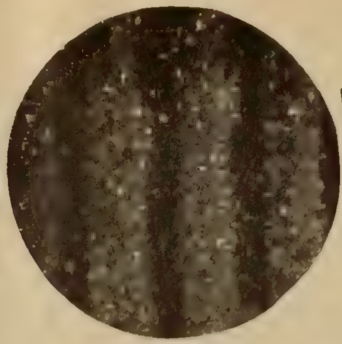


FIG. 11

FIG. 12

RECORD F
37 DIAMETERS

subsequent microscopical examination. Moreover, this method of attack would permit the examination of crystalline matter by polarized light and also, it would allow the individual particles to be gaged by micrometry.

After much laboratory work of the most painstaking order and innumerable failures which are usually incident to work of this kind a delicate mode of procedure was developed whereby a section of the surface measuring approximately one centimeter square and only a few thousandths of a millimeter in thickness could be removed from the record. These sections were then mounted on glass slides in the manner described above after which it was possible by means of the microscope "to look through the record" and see the nature and condition of the material forming the bottom of the record grooves. Even to one experienced in technical microscopy the results were startling and they seemed sufficiently convincing to warrant the speculation that the development of the phonograph record has not as yet reached its zenith. As a further aid in the investigation transverse sections also were prepared and a method of reproducing the record surface in a transparent medium was developed as will be described later. To reproduce the surfaces by photomicrography proved somewhat of a problem but by a special arrangement with a powerful illuminant together with the necessary optical system the photomicrographs reproduced here were taken.

In the selection of specimen records for examination every effort was made to secure thoroughly representative records from each manufacturer's product. In general, unused records of the latest production were procured from dealers whose sales are large and by careful selection it was felt that the results would be representative. In those cases where the record manufacturer also markets a phonograph the records were played on a machine of the same make; otherwise they were played on one of the standard available machines adapted to the record. The records selected include all of the standard makes with exception of the cheaper records in which a high degree of artistic or technical attainment should not be expected.

In order that the illustrations may be understood and correctly interpreted a brief description of record construction seems necessary. Phonograph records are made from that class of materials known as hot molded composition. They consist of a binder intimately mixed with suitable mineral and vegetable fillers and a small proportion of coloring matter. Under suitable conditions of temperature and pressure the mixture assumes a plastic condition and may be molded. The binder may be either a natural or synthetic gum or resin, or a combination of both. The commonly used natural resins or gums include shellac and rosin. The synthetic resins (phenolic condensation products) have the property of resisting deformation under moderately elevated temperatures and, too, they produce a very hard surface which resists abrasion. Consequently records made with these resins do not scratch and mar easily during handling. The natural resinous materials are often affected by heat and records made with them are apt to deform unless properly stored. Also the surface of such a record is somewhat soft and apt to be damaged by careless handling. The mineral fibers, such as rottenstone, chalk, etc., are used to impart hardness and strength. The vegetable fillers are usually cotton or wood fibers and their function is to help hold the mass tenaciously together and to counteract brittleness.

Figures 1 to 19 inclusive are photomicrographs of the nine prominent records which were selected for investigation. The bright spots are the particles which transmitted the light more brilliantly than the adjacent particles and from a consideration of the illustrations it seems evident that what to the eye appears to be smooth and polished is actually a rough and rugged road, at least in so far as the stylus is concerned.

From a critical examination of the illustrations one probably would conclude that record "H" should have the least surface noise and this assumption would check exactly with the facts. The record consists of a disk of cheap composition faced with a pure phenolic condensation product. Therefore, the record grooves are made up of a very smooth, hard, homogeneous substance, free from mineral and vegetable matter such as is found in other records. The irregularities shown in Figure 15 were found to consist of small cracks, voids and air bells and

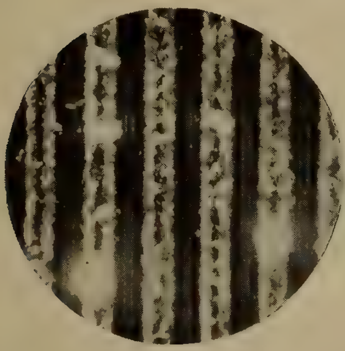


FIG. 13

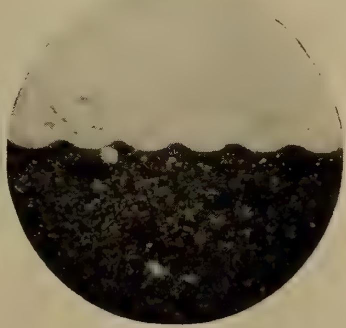


FIG. 14

RECORD G
37 DIAMETERS

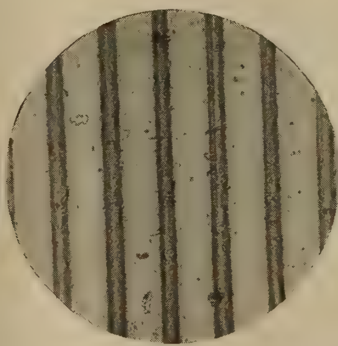


FIG. 15

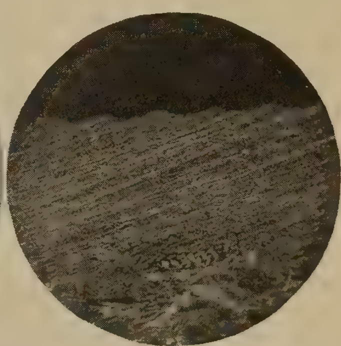
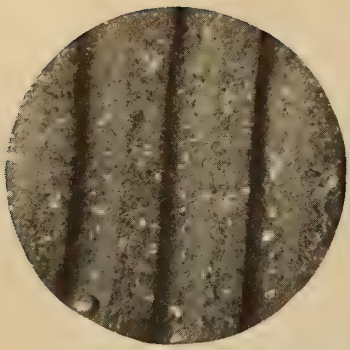
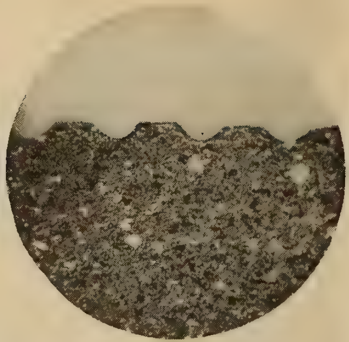
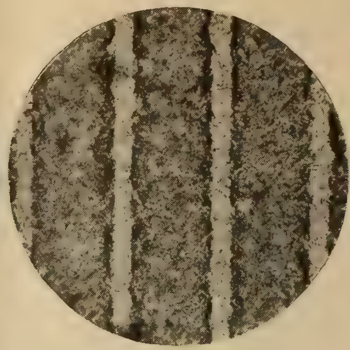


FIG. 16

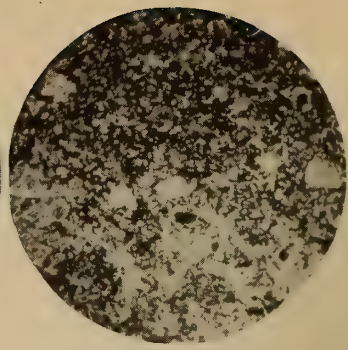
RECORD H
37 DIAMETERS

RECORD I
FIG. 17 37 DIAMETERS FIG. 18



TRANSPARENCY 75 DIAM.
FIG. 19 RECORD G



37 DIAM.
FIG. 20

also of foreign particle inclusions such as dust. This photomicrograph is of special interest because it shows the order of imperfections which commercial molding may be expected to yield when working with a clear homogeneous material. So far as freedom from surface noise is concerned this record left little to be desired but unfortunately the surface coating displayed a tendency to warp and crack; due, apparently, to an inherent physical weakness in the record construction.

On the listening test record "I," Figures 17 and 18, was found to be next in order of freedom from surface noise, although there was quite a gap between it and record "H." In most of the records the surface noise was not especially pronounced and probably would not be objectionable to the average listener except, perhaps, in records reproducing soft music. Figures 17 and 18 show clean-cut molding and quite uniform structure.

In addition to the usual scratching sound, occasional "snaps and cracks" are often heard and these seem to have their origin in a different source. In record "B," Figure 3, certain imperfections in the record surface are to be seen and it seems probable that when the stylus strikes such obstructions as these the reproducer must register some sort of a violent protest. These molding imperfections were found to be more pronounced in this particular record, but they were by no means absent in the other records. Record "B" also had considerable surface noise which one would expect from the nature of the structure as shown by Figures 3 and 4.

Record "F," Figures 11 and 12, illustrates a novelty in construction. In Figure 11 it will be seen that the record body consists of a coarse structure which is faced with a finer composition. Between the body and the surface coating on each side is a fibrous separator. The surface of this record is of finer structure than record "B" and, as might be expected, the surface noise was less intense.

Records "A," "C," "D" and "E" on the listening test were found to be much the same so far as surface noise was concerned. Some differences did exist but it will be seen from the illustrations that the surfaces are inclined to be rough and in some instances the structure is coarse.

As might be expected from Figures 13 and 14 record "G" had the most surface noise of any of the records studied. In some records the scratching assumed very disagreeable proportions and detracted greatly from the musical value of the record. The grooves were found to consist of small and large mineral particles and splintery bundles of wood fiber. The large mineral particles were present in abundance as will be noted and their origin was a mystery until treated by a method of microscopic analysis. Since a large proportion of the record consisted of wood flour it was decided to examine some representative samples of this material. The results showed that the wood flour carried large inclusions of mineral particles similar to those found in the record surface. Following the wood flour to its origin it was found to consist of sawdust ground to fineness in a stone mill. Apparently in this way particles of the grindstones were being conveyed to the record surface. In Figure 22 the coarse and splintery structure of the wood flour is shown by means of a photomicrograph taken by dark ground illumination. A large mineral particle is much in evidence. An idea of the extent to which mineral particles were found to be present in wood flour may be judged from Figure 20 which shows the inorganic matter found in about one per cent of the wood flour which could be heaped on a ten-cent piece. The wisdom of using material of this kind would seem open to serious consideration, especially in view of the fact that chemically separated wood fiber free from foreign inclusions may readily be obtained. Wood fiber of this nature is illustrated in Figure 21. It will be noted that the wood has been reduced to its ultimate fiber, which is the best possible condition for molding plastics.

As a further aid in the investigation a transparent medium which would take an impression from the record surface was developed, the idea being that differences in level would be disclosed by differences in the depth of color of the impression when viewed by transmitted light. That is, a mount of this kind when examined under the miscroscope would constitute a relief map of the record surface. Figure 19 is from an impression taken from record "G" and the similarity of Figures 13 and 19 is quite evident. In Figure 19 the light colored bands are the ridges and the broad darker bands are the grooves from which it is clear that a dark area indicates a depression in the record surface and a light area an elevation. This method of examination has the advantage of being quicker but does not permit qualitative and quantitative analyses by means of the microscope.

From a consideration of the data obtained it would seem that future improvements in surface conditions appear most hopeful along lines which will result in a finer and a more homogeneous structure.

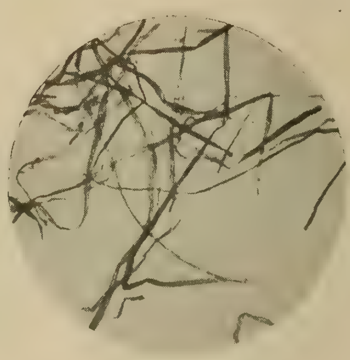


FIG. 21. FIBERS OF WHITE SPRUCE SEPARATED BY CHEMICAL MEANS. ENLARGED 37 DIAMETERS

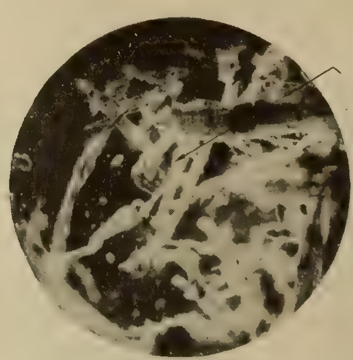


FIG. 22. GROUND WOOD FLOUR WITH COARSE MINERAL PARTICLE INDICATED BY THE ARROW

Progress in the Art of Taking Moving Pictures

Cinematography in Germany

IN a recent number of the German magazine, *Umschau*, Frankfurt-am-Main, Walter Thielemann gives some interesting information about cinematography. He writes: Even during the years of the war there has been much new discovery in invention with respect to the art of the cinematography on the part of the German technologists. Many of these things were stolen by the Allies during the abeyance of patent rights. Those inventors, however, who were clever enough to renounce their patent rights during the war and deferred the publication of their inventions until the coming of peace, are now giving to us a number of new processes in the technique of the cinematograph.

One such invention which promises to be epoch making is the work of a German-Austrian, who during the war discovered a method of preventing the annoying flickering of the pictures during the projection of the films. The flickering of the film projection is caused by the fact that the strip of film is in constant motion while the source of light is steady. This disturbance is remedied by the new invention in the following manner: by a system of movable mirrors the light source accompanies each position of the entire strip of film upon its progress and with the same rate of speed. By means of this arrangement perfectly clear and definite projection images are obtained for every part of a film; the flickering of the film may soon be expected, therefore, to be a thing of the past.

Another invention, "the film opera," works in connection with real singers and in front of the projection surface of the film there is a complete orchestra assisted by living singers. The director of the orchestra is photographed upon the film at the same time that the regular moving picture performers are photographed. The musicians and singers watch his motion and he gives them all the signals that a regular leader of the orchestra would do. At the same time the public can see upon the lower edge of the film the corresponding metronomic signs which exactly correspond with the signals given by the orchestra conductor shown upon the film. Really surprising results have been obtained in this way in the film operettas produced in the last few months. The most melancholy thing about this purely German invention is that by the stealing of patents mentioned above, foreign countries can employ this device to the injury of our own industrial firms.

Among the manifold novelties in the list of cinema apparatus which are especially suited to assist the arts of education, one very new and valuable one is that by means of which the progress of the film may be arrested for a time when desired. Hitherto when the film was stopped its highly inflammable material was almost certain to take fire. The new invention enables the operator to stop the passage of the film by means of merely pressing a button and by pressing a second button it is possible to make it run backwards. Hence, when it is desired to explain and make impressive a specially important part of an educational film, or when the students desire to ask questions about it, the given portion of the film may be held or shown repeatedly as long as the instructor wishes. This novel invention which has already been amply tested, will doubtless give great satisfaction to teachers and lecturers.

The use of films for instruction has made special progress in the last few months, particularly with respect to microscopic moving pictures. Before the war these were exclusively prepared by French film firms. Among these we may mention interesting microscopic moving pictures, taken from life, of the water flea, a crab-like animal scarcely two milimeters long, which is shown enlarged several thousand times. The observer is able to see not only the externally visible motions of the feet, the antennae, etc., of this minute insect, but also the pulsation of its primitive heart sac, the movement of its eyes which contain dark pigment set about with chalk crystals, and even the functioning of the muscles of the eyes, with perfect clearness. Other films exhibit diagrams showing especially the introduction of pathogenic germs into human organs and the resulting sickening of the whole body, as also studies of the life of bees, etc.

A Berlin engineer has succeeded in retaining speech upon a thin sheet of celluloid and has thus solved a difficult problem which countless investigators have worked at for many years, and before which even Edison's skill has recoiled. By the aid of a new recording process it has become possible to replace the heavy phonograph plates, whose material is at the present time both costly and difficult to obtain, by thin, flexible sheets of celluloid about 12 cm. in diameter; the advantage in the employment of these is that they practically do away with the irritating "scraping" accompanying sounds, which ordinarily injure the tone. Since the plates can be replaced by a ribbon the *talking film*, which has been sought for so many years, has at last been discovered. The greatest practical advantage of the new dicovery consists in the great cheapness of the new plates, which will enable the phonograph to be used for the general instruction and entertainment of all classes, and may be expected to be of peculiar service to the men blinded in the war.

Film caricatures, i.e., pictures which appear upon the white screen as if drawn at lightening speed and with skill by the hand of an invisible master, have lately been extremely popular. As soon as the drawing of the pictures has been completed the figures begin to move. To the layman this appears most mysterious. In reality, however, the film caricatures are drawn exactly as shown upon the film except that they are done very slowly instead of very rapidly, the rapid passage of the film giving the illusion. In preparing such pictures the artist first makes a sketch of the proposed work. He then covers the pencil lines of his sketch with white tempera, so that they can still be recognized at very close range. The work is then placed before the camera. The artist draws a line with the dark color and steps aside, whereupon the operator takes a picture of this single line. The artist then makes a second stroke and steps aside once more until the camera has recorded this, and so on till the work is finished. If it is desired to have the figures move, the movable portions are cut out of paper after being drawn and then moved in front of the apparatus. Making such pictures is not only exceedingly difficult, but demands the most exact precision. However, a surprising degree of perfection in their preparation has been attained during the last few years.

STERLING SILVER.

The Engineer (English), October 10th, publishes the paper of Smith and Turner on "The Properties of Standard or Sterling Silver." This silver derives its name from the fact that it has been the legal standard alloy for all British silver coinage and silver plate. It contains 92.5 per cent silver and is the only silver alloy of any industrial importance. The authors found that the temperature of the metal in the crucible should be about 1200° Centigrade when ready for casting, and that the stream of silver during pouring was about 1113° Centigrade. When casting the alloy precautions must be taken to secure homogenous composition throughout the ingot for there is a tendency for the silver to become concentrated at the center of the ingot. Ordinarily, 670° Centigrade is the best temperature for annealing and usually this process is completed in some twenty to thirty minutes. The maximum Brinell hardness of standard silver was found to be about 183, and the tensile strength varied, according to the method of casting, from 22,000 to 28,000 pounds per square inch.

A New Method of Welding

French System of Holding the Welding Rod to the Rear of the Torch

THE usual method employed in autogenous welding consists in holding the torch inclined in the direction of the place to be welded and imparting to it a slight vibratory movement. A new method has been recently described in the French magazine *Revue da la Soudure Autogène* (July-August) called *Soudure en arrière* (Welding to the Rear). In this process the welding rod or filler rod (i.e., the stick which the operator holds in front of the blow pipe and which gradually melts and fills up the space between the edges of the two pieces of

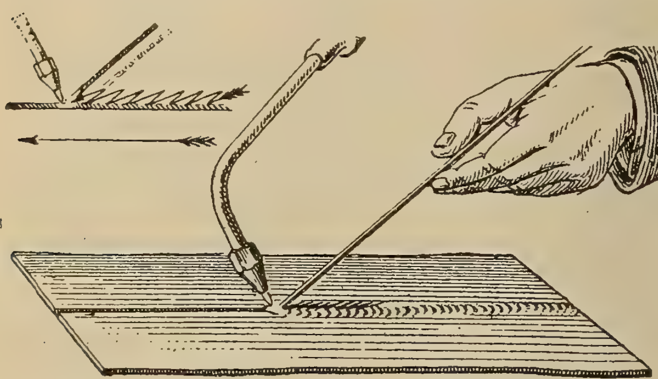


FIG. 1. WELDING OF THICK SHEETS OF METAL

metal that are being joined), follows the torch instead of preceding it. This process, which was devised for welding soft steel by M. Roulleau during the war, and which has been employed in a number of factories, both in Italy and in France, presents considerable advantages: the metal is sounder, the rapidity of advance is greater, and, finally, there is a saving of at least 25 per cent in labor, in gas, and in filler metal.

The fusion of the filler metal is affected no longer directly by the point of the flame but by the heat proceeding from the entire flame, the torch being inclined towards the rear, i.e., towards the welding rod.

The stick of filler metal is pretty smartly inclined with respect to the line of the welding in the forward direction, i.e., in the direction contrary to that of the inclination of the flame. The angle which appears to be the most favorable between the line of welding and the filler rod is 45 deg. for thicknesses starting at 6 to 7 mm. and a little bit less below these down to 30 deg. for weldings upon sheets of metal 3 mm. in thickness.

This inclination, furthermore, is a function of the movement which is imparted to the end of the filler rod in the line of the welding. In thicknesses of about 6 mm. this movement consists in causing the extremity of the filler rod to

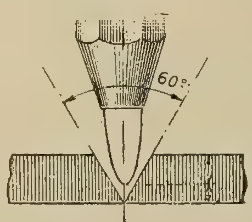


FIG. 3. POSITION OF THE TORCH, TIP OF FLAME IN ANGLE FORMED BY THE CHAMFERS

melt, by moving alternately from one side to the other of the line of welding (Fig. 1). In thicknesses below 6 mm. the movement becomes at first ellipsoidal in character and with sheets of metal having a thickness of from 3 to 4 mm. (and still more so for these having a thickness of 2 mm.) it finally exhibits a back and forth longitudinal movement unaccompanied by a transverse movement (Fig. 2). In both cases the extremity of the filler rod remains constantly immersed in the fused metal.

In order that the welding line may present a homogeneous aspect it is advisable to operate at the same rate of speed from start to finish. Otherwise if one moves the torch too rapidly at one end the free fusion and the regular advance will not be obtained until after the lapse of a certain length of time from the beginning of the welding. It is well, however, previously to heat the sheets of metal with the blow pipe along the line of the weld for a breadth of a few centimeters. The blow pipe and the filler stick are held, as indicated, the tip of the flame penetrating thoroughly into the angle of the opposite chamfers or beveled edges of the sheets of metal, and the first melting is obtained by imparting a slight gyratory movement; then the filler rod is immediately introduced into the molten metal, while at the same time the blow pipe begins to advance at a regular rate of speed. The filler rod, on the other hand, which immediately follows the flame, is given a reciprocating movement, either perpendicular to the edges of the line of welding, or else more or less elliptical or longitudinal, according to the thickness of the metal, but always retaining the same angle of inclination.

By following this method the welding is accomplished in a normal and very continuous fashion. The operator must be careful to employ an amount of filler sufficient to entirely close the line of welding with neither an excess nor a deficiency. Upon arriving at the end of the line of welding the

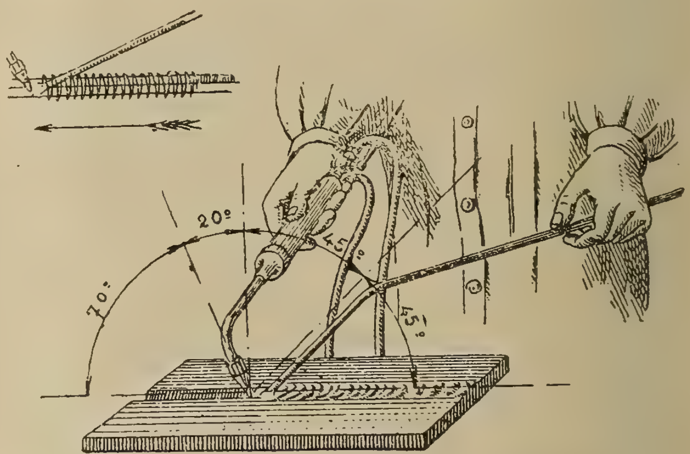


FIG. 2. WELDING OF THIN SHEETS OF METAL

position of the blow pipe is changed as required, in order to secure a neat finish, the blow pipe and the welding stick being skilfully manipulated as in the ordinary process.

Since the molten metal is directed towards the rear, it is always the faces of the chamfers which are attacked; the welding is of the character known as *bien traversé* (well filled), and smears are almost impossible. However, the operator should never proceed with too much speed, but must go slow enough to give the faces of the chamfers time fully to melt, while, at the same time, avoiding the creation, by going too slow, of "candles" of melted metal on the opposite side of the welding by reason of too great an application of heat at the point of the V (Fig. 3).

ELECTROPERCUSSIVE WELDING.

E. VIALL describes a method of jointing wires by connecting the two pieces to the terminals of a charged condenser, and bringing them suddenly together with some force. Sufficient electrical energy is liberated by the discharge to melt the wires, while the force of the blow welds them together.

A machine suitable for jointing aluminum and other wires up to No. 13 gage is described. One wire is held in a chuck at the base of the apparatus, while the other is clamped into a holder free to slide in vertical guides. The holders are connected to the terminals of an electrolytic condenser by a circuit containing an adjustable inductance, and are kept short-circuited till required. The condenser is coupled up to a source of supply through resistances. The wires have their ends prepared by a special cutter, the switch is opened and the upper holder is allowed to fall, when, if all adjustments are correct, a perfect weld is immediately made. Oscillographic tests with No. 18 B. & S. aluminum wire show that the power expended at the weld reaches 23 kw. for an instant, but the entire weld is made in 0.0012 sec., so the total energy is about 0.00000123 kw-hr. per weld. The process is well adapted to welding copper connections to aluminum.—*American Machinist*, March 20, 1920. Abstracted by *The Technical Review.*

THE GREAT HYDROELECTRIC PLANT AT KEOKUK.

THE Mississippi River Power Company's power plant at Keokuk, Iowa, is by far the greatest low-head hydroelectric development ever undertaken. The entire structure is built of monolithic concrete and includes a dam, power house, navigation lock and dry dock. It is located at the foot of the Des Moines Rapids. It is two miles long and is provided with a normal working head for hydraulic machinery of 32 feet. The discharge of the river, at the site of the power station, where it is approximately a mile wide, is 200,000 cu. ft. per sec. at low water and 372,500 cu. ft. per sec. at the flood stage, which discharge made possible the project.

A 4,560-ft. spillway dam of the gravity section type which is surmounted by a bridge, extends from Hamilton, Ill., on the east side of the river, to the power house which is near the west side of the river. It consists of 119 arched spans each having 30-ft. openings and 6-ft. piers. Each of these 30-ft. spillways may be closed by a gate or wier, in other words, there are 3,570 ft. of spillway.

In order that drift and ice may be excluded from the forebay, a 2,340-ft. fender pier was constructed. There is a 300-ft. opening between the shore abutment and the end of the pier to allow the passage of river traffic. When navigation is closed, or when there is a large amount of floating matter in the river, this opening is closed by means of a floating boom.

The completed power house will be 1,700 feet by 123 feet, and will provide room for 30 units each comprising a 10,000-hp. single-runner vertical Francis turbine connected to a vertical 9,000-kva., 11,000-volt, 25-cycle, three-phase generator operated at 577 r.p.m. The present structure is only half of that called for by the plans, and provides for only 15 main generating units. From the forebay the water passes through the gate openings in the gatehouse section of the building., thence entering four branch intake tubes for each 10,000-hp. turbine. These four entry openings, 22 ft. by 7.5 ft. deliver the water to the scroll chamber at the sides and rear of the turbine setting. By the design of the scroll chamber, 39 ft. in diameter and molded in concrete to follow the mathematical curvature required, the water is impinged upon the turbine blades from all sides with equal force and velocity. The draft tubes, 18 ft. in diameter at the rotor, enlarge rapidly as they assume a horizontal direction to empty into the tail race. Because of this design the water, as it enters, moves at a speed of 14 ft. per second and is discharged into the tail pool at about 4 ft. per sec.

A short dam extending downstream from the power house, a navigation lock and a dry lock at the west shore, form the forebay of the power house. The lock is a single 40-ft. lift, the chamber of which is 400 ft. by 110 ft., and may be filled in 10 minutes and emptied in 12 minutes. One of the features of this lock is an upstream gate, which may be described as a single leaf with a void chamber. This gate is operated as follows: To open it the chamber is filled with compressed air, and because of the buoyant effect it floats into place; to close it, the compressed air is allowed to escape, and it sinks into the chamber provided for it because of its weight.

At the present time this station provides 110,000 h.p. to St. Louis, East St. Louis, Alton, Hannibal, Quincy, Burlington, Ft. Madison and adjacent territory and, thus, serves a population of about 1,120,000.—From *Mechanical Engineering,* April, 1920, pp. 228-29.

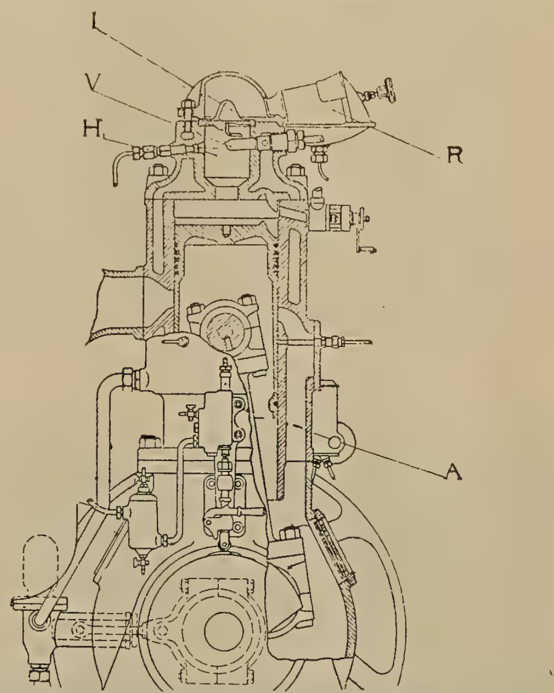
BERGSUND ORIGINAL SURFACE-IGNITION TYPE ENGINE.

THE Bergsund engine is now being built in Sweden but it is likely to be introduced soon on the market.

Its design does not differ essentially from that of similar engines now known. It is shown in section in the accompanying drawing.

The cycle is as follows:

The projecting piece V has a double duty as the fuel is sprayed on it at an acute angle in an almost solid stream, and is split by it into fine particles. And, in order to avoid chance of misfire at light loads, the lipped ignition disk V_1,



BERGSUND ORIGINAL SURFACE IGNITION TYPE ENGINE TYPE ENGINE

termed the light-load ignition surface, is fitted just above it, and this enables the engine to run for long periods without load, or without the use of the blow-torch.

Fuel oil is injected by the pump into the hot-bulb "T" via surface V, which is heated when starting by transmission of heat from the double-lipped disk I, which is made red-hot by the blow lamp R. After the engine has been running a short time, the blow lamp is extinguished and the projection R and the ignition plate are kept hot by the temperature of combustion. It will be noticed that both the hot bulb and the injection nozzle H immediately before the piston reaches top center, and is sprayed on to the surface of the projecting cylinder head are water-cooled.

Fuel is fed to the injector by the pump A which is actuated by a cam on the governor. The governor regulates the position of the cam in such a manner that the stroke of the pump is suited to the load of the engine, hence the quantity of the fuel being varied. Before entering the cylinder, the fuel-oil is passed through to separate filters, one of which may be taken out and cleansed while the engine is working. All troubles from the choking-up of the fuel oil valves and the nozzle are obviated by this arrangement.—*Motorship*, Vol. 5, No. 6, April, 1920, pp. 324-326.

Drilling an Oil Well in Pennsylvania

Methods of Boring and Details of Machinery Used

By Herbert T. Wade

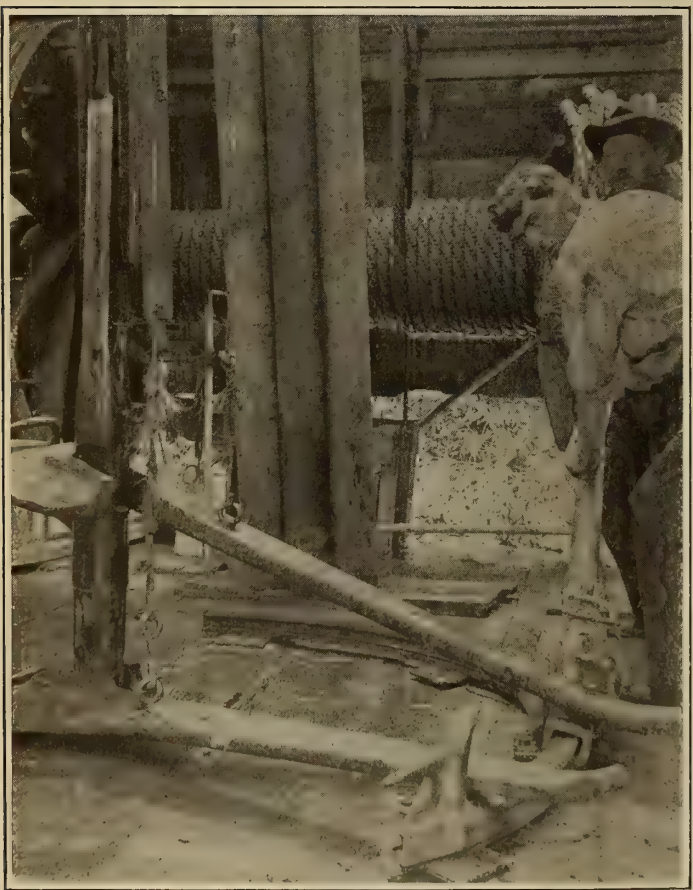
THE sinking of bore holes into the surface of the earth in the quest for petroleum or natural gas involves interesting equipment as well as operation, which has been developed in the course of comparatively few years. Despite the general rough appearance of a drilling installation in the oil fields, in most instances drilling methods and machines are quite efficient and extraordinary depths have been attained in a number of instances.

To appreciate the general nature of the operation it must be borne in mind that there are two fundamental elements in sinking a deep bore hole, namely, drilling and hoisting, and the installation must be designed with these ends always in view. Drilling may be done either by percussion, hydraulic, or abrasive methods, depending upon the nature of the material to be penetrated, and in different countries and in different oil fields there are variations in the processes and equipment. The American standard cable or percussive system developed in the Appalachian field consists of cable tool drilling or raising a steel drill by a cable and permitting it to fall of its own weight and thus make its way through the material. In California and other fields the rotary system is employed where a column of pipe whose lower end is fitted with a cutting tool is turned in the bore hole.

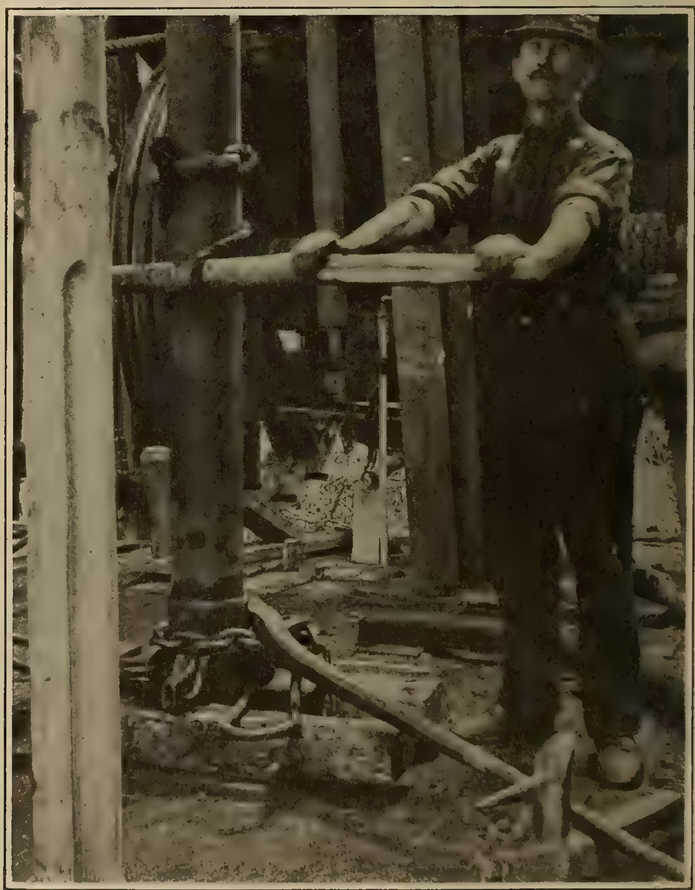
In the main there are two grand groups of drilling installations, first the portable or drilling machine readily moved and generally speaking limited by about 2,000 feet depth of operation, and secondly the drilling rig designed to be installed permanently at the selected location, and in some cases susceptible of being dismantled, removed and reassembled and erected elsewhere in equally permanent form.

The leading feature of the drilling rig is of course the tower so familiar in the landscape of any oil field. A drilling outfit such as may be found in Pennsylvania, West Virginia, Oklahoma, or elsewhere in the United States consists not only of the drilling structure, that is the derrick and its appurtenances, but also the tools, engines, boiler, rope, and other accessories. These outfits in many cases are owned and operated by contractors, and in sinking a gas or oil well by contract it is usual for the drilling rig and casing, that is, the protecting pipe lining the bore hole, to be furnished by the owner, while the tools, engines, boilers, etc., are supplied by the contractor who is paid on the basis of the distance drilled.

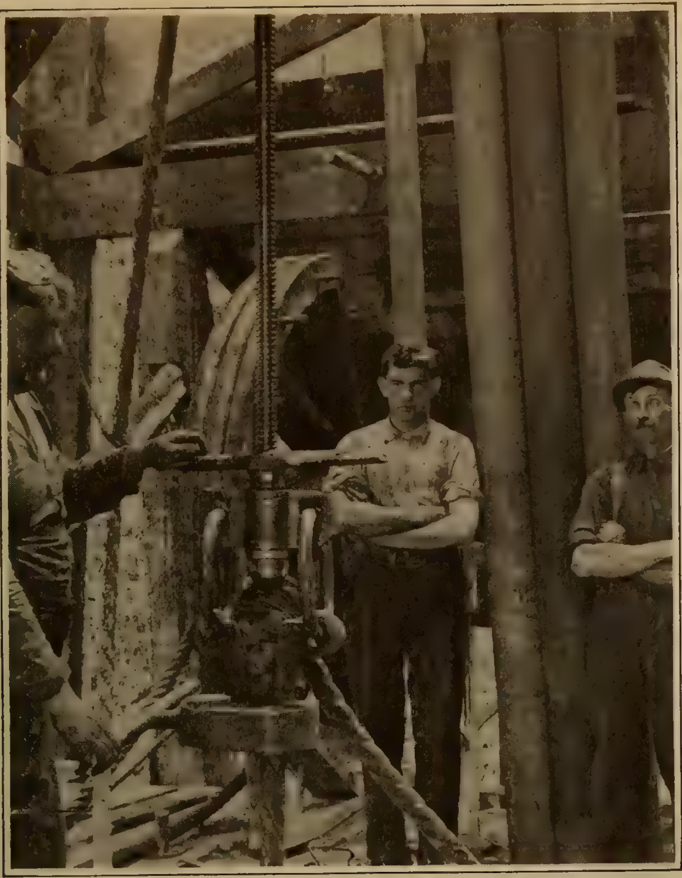
The most usual equipment seen is the old-fashioned timber tower rig, parts of which are shown in the accompanying illustrations. Naturally the drilling rig is an evolution which began with a spring pole supported on a tripod or forked post, and carrying suspended at one end the drill. This was succeeded by a braced mast single or double. Then came the modern four-legged braced derrick of timber intended to remain permanent. In all of these the object was to secure an arrangement which would raise and lower a drill tool or bit, and later serve to support and lower a lining of iron or steel pipe or casing in the bore hole. The next development of the timber derrick was to design it so that it could be put together readily with bolts and then taken down and removed elsewhere in case of lack of success or for other reasons. Follow-



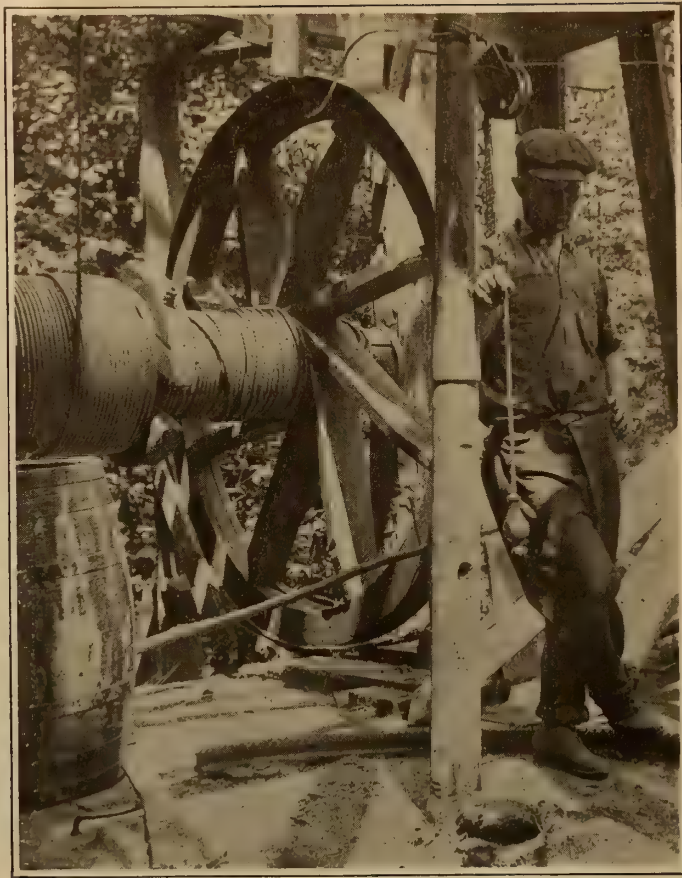
DRILLING BIT BEING SCREWED WITH A 200-LB. WRENCH. NOTE "BULL WHEEL" IN THE BACKGROUND



THE CASING BEING SCREWED TOGETHER WITH "CHAIN TONGUES" AND "NEVER SLIP" PIPE WRENCHES



VIEW OF THE TEMPER SCREW. THIS ADJUSTS THE DEPTH OF THE DRILL



STEEL TAPE BEING LET DOWN INTO THE WELL TO MEASURE THE PROGRESS DEPTH

ing all structural development there came derricks constructed from the abundant supply of pipe to be found around oil wells, and then a special steel structure designed to furnish with greater strength and permanence the facilities required. A long panel construction at first was turned out by construction engineers based in many cases rather upon theoretical and preconceived ideas than upon the demands and standards of field practice, but this later was modified in a steel derrick with short panels in which the best features of the long established wooden tower were retained and the demands of the men in the field met. Today the most approved practice demands the use in new installations of structural steel not only for the towers, but for the support of the machinery, framing of the buildings, which are covered with sheet metal, and wherever else required.

The comparative recency of all this may be appreciated from the fact that while a well for brine had been sunk as early as 1806 at Charlestown, W. Va., the first well drilled for oil was the Drake well sunk by hand at Titusville, Pa., in 1859. The beam either in the form of a spring pole or balanced beam already referred to was employed by the Chinese and was a feature of early installations in the United States.

As suggested this developed into the four-legged braced wooden tower which by 1866 had come into general use, and as modified in many respects and of increased size is widely found today in the United States. The wooden rig had and has the advantage of speedy and easy construction and it could be readily strengthened in case it was found too light, while timber was generally accessible in the oil fields. Furthermore, in case the well proved productive the tower and power plant could be left in position for the pumping machinery which would take the place of the drilling outfit.

It will be apparent that the arrangements mentioned are necessary to deal with the great depths involved in lowering drills, etc., and in fact with a well running over 3,000 feet in depth careful provision and adequate and permanent equipment must be installed. The derrick which is from 60 to 110 feet in height is required to facilitate the hoisting and lowering of the string of drilling tools, the casing, sand pump, and other adjuncts. At the top is the crown pulley over which passes the cable, usually a 2-inch manilla rope which carries the string of tools that terminate in the drill or cutting bit. The cable is connected to a walking beam by a "temper screw," shown in our illustration, which also permits the drill to be lowered between strokes and its cutting regulated. The walking beam is carried on a "Samson post" and is connected at the opposite end from the cable by a pitman with a so-called band wheel driven by a steam engine or directly attached to the wrist pin of the main driving shaft, the object being to give through the walking beam an up and down motion to the cable carrying the drilling tools. The boiler is usually located some distance from the engine for reasons of safety.

The drilling tools in size and weight adapted to the nature of the material being penetrated and the depth of the operation, are duly lifted and fall under their own weight, pulverizing the rock. These tools are strung along in a formidable array and their total length amounting to some sixty feet or so, in part is responsible for the height of the derrick. The arrangement of tools from the bottom up is as follows: First comes the drill proper or cutting bit, varying from the broad cutting edge found in the "spudding" bit used in earth or sand at the beginning of the bore hole to the drilling bits for rock, their cutting edges varying of course with the diameter of the hole. The bits also vary in weight and are threaded at the top so as to be screwed to the next element, namely, the augur stem a long steel bar anywhere from 12 to 45 feet or so in length. Next come the jars, a loose link arrangement capable of about 16 inches movement, whose function is to free the drill by affording an upward jarring blow on the up stroke. Then comes the sinker bar and finally the rope socket at its upper end. It will be seen that screwing the elements of the drilling section together can be done only by the use of large

wrenches which hold and turn the bits and other bars. The illustration shows a couple of these 200-pound wrenches being used in screwing a drilling bit to the augur stem.

While the temper screw provides for the depth adjustment of the drill without removing the tools, yet from time to time these must be raised clear of the bore and new drills substituted. In that case the cable which passes over the crown pulley to the bull wheel is regularly wound up and the tools hoisted out. The loose material such as the pulverized rock and sand is removed by a sand pump and a bailer with a dart valve at the bottom is lowered on a separate and small line passing over its own pulley and wound up on its own windlass. It may be said here that the bailer in addition to clearing the bore also gives the indications of the material that is being penetrated and samples are taken, washed, laid out in order, for the study of the driller, engineer or geologist, and traces of oil or oil bearing sands are carefully looked for and noted.

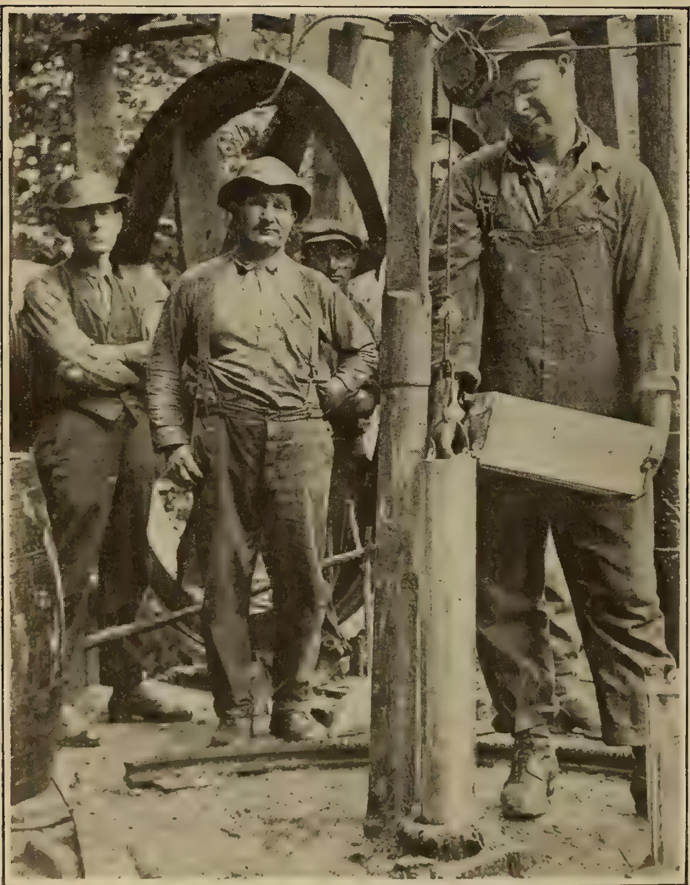
It must not be inferred that the regular drilling operations begins at once in sinking the bore hole. There must be secured at first sufficient depth to permit the string of tools to be lowered and often the first drilling is through earth, clay, sand or gravel, where it may be possible to sink a steel pipe directly or by hydraulic or other means until rock is reached or the spudding tool referred to may be used. This tool as stated has a longer cutting edge, usually about 12 inches and is not operated from the walking beam but is attached to the cable and lifted and dropped by means of a jerk line, one end of which is attached to a crank or wrist pin on the band wheel or main shaft and the other to the cable near the bull wheel. In this way a short, quick stroke is communicated to the cable and drill which cuts its way through the surface soil or sand quite rapidly.

At first some form of large casing may be inserted in the bore or a drive pipe is lowered until rock is reached. When the regular rock drilling begins the bore must be protected from caving or the ingress of water by means of a casing of iron or steel pipe which is carefully jointed sometimes with packing rings and lowered down in the well; this operation of the pipe wrench arrangement being shown in one of the illustrations. Usually in the case of a deep well the lining or casing diminishes in diameter as the depth increases much after the fashion of a telescope tube.

The work of the contractor sinking the well may run smoothly and therefore profitably to him, or he may encounter difficulties that will diminish his profit or even involve a loss. The cable may break, dropping the tools. The tools themselves may come unscrewed or the stem may break. The casing may drop into the hole, or other mishaps occur, many of which involve "fishing," often an arduous job for which many tools are provided. Usually this work is successful, but it may require that the bore must be abandoned and a new well sunk.

Ordinarily enough is known of the nature of the location so as to plan the drilling, and the size of the hole started depends upon the number of times it is to be cased. Of course successively smaller drills are used the greater the depth. The driller at the tempering screw is able to tell the nature of the material, for a rapid letting out indicates a soft rock such as coals or shales are being encountered, while the reverse is true for the hard strata. The drill on removal from working in soft material will have a muddy appearance, but if it has been cutting through hard shale the bit and stem will appear bright and polished, while in solid, hard formations the cutting edge of the bit will be roughened in such a way that to the expert the "feel" will indicate conditions.

If a well of promise is obtained, and also when it is desired to increase the flow of oil or attempt to restore a decadent well, the next consideration is shooting in order to shatter the rock or pay sand at the bottom and thus permit a freer flow to the well. This shooting or torpedoing is done by lowering a shell filled with nitro-glycerine to an amount



SHELL BEING FILLED WITH NITROGLYCERINE PREPARATORY TO SHOOTING THE WELL. NOTE DRILL ALONGSIDE

A "JACK SQUIB" LOADED WITH DYNAMITE CAP AND FUSE READY TO BE DROPPED INTO A WELL FOR A SHOT

sufficient to occupy the entire distance opposite the pay streak or sand and then exploding it by some form of detonator. The shell is from 3 to 5 inches in diameter and from 5 to 20 feet in length sometimes in sections and is detonated either by means of a "go-devil," a leaden weight sent down on a cord to strike a percussion cap, or in more modern practice, by a squib loaded with dynamite and having a time fuze as well as percussion mechanism, which is dropped to the bottom and there detonates the nitro-glycerine.

The oil well is finished by lowering a pipe within the casing through which the oil flows under natural pressure or is pumped. It is then led to field storage tanks and to pipe lines to the refineries or to storage tanks.

While in these unsettled times it is of little value to refer to costs, yet it may be stated that under previous normal conditions the cost of drilling ran from $1 to $15 a foot or more, the deeper the well the greater the cost and the rate of progress was said to run from 60 feet a day to 10 feet for the deeper bores. It has been estimated that the cost of drilling a 3,000-foot well under present conditions would run from $50,000 to $80,000 or more.

The illustrations shown and the methods described apply only to the Appalachian field, but the modifications in other American regions, except perhaps in California, where there is more rotary drilling, are minor. With the increased attention given to oil development there have been improvements in machinery to which competent mechanical engineers and manufacturers have directed their attention so that much of the rough and ready equipment of earlier days has been supplanted by better machinery and devices. There are also diversities from American practice in Canada and of course to a much greater extent in foreign countries.

Peat as a Possible Source of Industrial Power*

Economic Factors Involved in Its Competition with Coal

By Herbert Philipp

THE use of peat as a source of heat goes back beyond the historical period into the ancient history of the early tribes in northern Germany. Pliny, the Roman naturalist, gives us possibly the first indication of the use of peat. He reports that the Teutons on the border of the North Sea dried and burned mud, what we now would call peat. In Ireland, Great Britain, Russia, Scandinavia, Germany, Holland and parts of France peat has been used as a fuel since time immemorial. The peat was cut from the bog very much in the same manner as it is still being done in many parts of Europe, where it is cut in brick shapes, allowed to dry in the wind and sun and stacked up, just as the American farmer piles his cord wood.

It is only in the last seventy years that any progress has developed in this industry, and although very little has been done in this country to obtain efficient results in using peat as a source of power, much can be expected in the near future of making this resource valuable and an economic factor in our industrial life.

EXTENT AND FORMATION OF PEAT DEPOSITS.

Peat is disintegrated vegetable matter accumulated in areas of poor drainage where the chemical decomposition has been partly retarded according to a variety of conditions. Some of the conditions have resulted in complete decay, so that the original substances have disappeared, while others have simply resulted in the loss of more easily changed compounds and gaseous elements, the material retaining its original form and mechanical structure. The deposits of peat are not uniformly distributed over our country, but occur in practically every state east of the Dakotas and north of the Carolinas to the Canadian border. This is supplemented by deposits all along the Atlantic coast, the state of Florida and across Texas to the Mexican border. In the Pacific coast states are some areas of peat deposits, especially in California and in the valleys of some of the lakes and rivers of Oregon and Washington. It is estimated that there are approximately 12,000 square miles of peat deposits in the United States of an average depth of 9 feet which would represent a total of about 14,000,000,000 tons of fuel, provided the whole were converted into peat fuel, which is no small resource and represents a possible means of furnishing heat and power for a considerable number of years.

It is only in recent years that peat has become of enough interest in this country to endeavor to classify the various kinds which are made. This work is being undertaken by Dr. Alfred P. Dachnowski of the U. S. Bureau of Plant Industry, and his initial attempt represents an admirable contribution to our peat literature. The terms muck, humus, moor, marsh (fen), bog, heath and swamp are terms used without any definite relation to the stage of development of the peat in the deposit. These terms usually relate to the marked physiognomy of vegetation appearing on the deposit. A peat deposit can be defined as a compact accumulation of plant remains of at least 8 to 10 inches (20 to 25 cm.) in thickness. No deposit containing more than 40 per cent of mineral matter must be included in this definition. Peat deposits usually occur upon gentle slopes, flat areas, in shallow depressions on the earth's surface which are poorly drained so that the surface is always wet or covered by water.

Owing to the various conditions under which peat deposits have been formed and to the various types of vegetable matter composing them and also to the various locations and climatic changes to which they have been exposed, each deposit is practically a study in itself. There are possibly no two deposits that are exactly alike, although a large number may be very similar in composition. This explains one of the reasons why difficulties have been met with in trying to work one deposit by means adapted on another deposit.

GROWTH OF PEAT INDUSTRY.

A peat industry exists in this country, and has grown steadily the last twelve years till it now represents a real industry. However, only a small quantity of peat up to the present time has been manufactured for fuel purposes, the largest amounts being used in agriculture and in the fertilizer industry. The statistics in the table show the amount of peat produced and also the quantity used for fuel purposes.

Crude Air-Dried Peat and Peat Fuel Produced in the United States, 1908-1918.

Year	Total Peat Produced Short Tons	Total Peat Fuel Used Short Tons
1908	24,800	900
1909	29,167	1,145
1910	37,024	......
1911	55,143	300
1912	47,093	1,300
1913	33,260	......
1914	47,093	1,925
1915	42,284	......
1916	52,506	......
1917	97,363	......
1918	151,521	20,567

*Paper read before the New York Section of the American Electrochemical Society, Feb. 27, 1920.

It will be noted that during the last few years the production of peat has practically trebled due to the extensive application of this material in fertilizers. It will be well to mention here that peat in this country is generally comparatively rich in nitrogen, and that is the reason why the use of peat in agriculture is proportionately greater in the United States. The peat fuel production was negligible until 1918, when the high price of coal gave quite an impetus to this industry, and the future offers very promising developments for a successful peat fuel industry in this country.

In Europe practically all the peat which is excavated is used for fuel purposes. Since coal has become high in price and as far as we can determine will remain so, peat becomes an economic factor in our future industrial progress.

MANY FAILURES TO PRODUCE PEAT ECONOMICALLY.

A large number of attempts have been made in the past to produce peat fuel economically, but the majority have proved uncommercial and we cannot speak of any successful peat fuel undertakings before 1918. The large number of failures were due to many factors which were, chiefly, lack of capital, poor engineering, difficulties of distribution, prejudice, stock jobbing, and competition of low priced coal. From this it will be seen that too many efforts have been made with small capital and poor engineering ability to allow the industry to get on its feet, and that has for years given the industry a bad reputation and prevented any attempts being made on a big scale and has generally created ridicule in suggesting a development of a peat fuel industry. With the present high price of fuel and the inability to obtain a steady supply, a peat fuel industry is now looked upon as a remunerative possibility.

There is more than one way of utilizing peat for the production of industrial power, yet whatever method is used the peat must first be excavated from the deposit, and the economic excavation of peat has been the biggest bugbear in the peat industry.

OPERATION FEASIBLE ONLY IN DRY SEASON.

The average peat deposit contains from 80 to 90 per cent water, and that must be economically driven off to make the peat available as fuel. It will therefore be easily realized that for every ton of raw peat excavated there is only 100 to 400 lb. of theoretically dry peat available. Peat deposits vary, and according to the grade of decomposition they will dry in the air at various rates. The more highly a peat is decomposed the more quickly will the moisture evaporate and the more fibrous the material is the more slowly will it evaporate. This phenomenon is due to the fact that the moisture present is not all there as absorbed moisture, but the water present is in the cells of the vegetable mass. It is therefore necessary in most cases to pass the peat through a pugging or macerating mill.

DEPENDENCE ON LOCAL CLIMATIC CONDITIONS.

In order to obtain a cheap fuel it can be inferred that peat cannot afford to be handled very much, and therefore the larger part of the drying has to take place on or near the deposit. It is manifestly unfeasible to use any artificial heat for producing peat fuel. However, there are conditions where waste heat can be used to advantage to reduce the moisture content of peat, as will be shown later. There is no cheaper method of drying than by nature herself, and the sun and wind have to accomplish the larger part of the drying in any development of a peat fuel plant. This shows how dependent the industry is on local climatic conditions—not only on the total hours of sunshine, but also on the winds and humidity of the atmosphere. Further, the temperatures of the season play a big factor in the excavation and drying of peat; it is impossible to excavate peat when the ground is frozen. In other words, enough material has to be excavated in the good season of the year to supply a plant for the whole twelve months, and this is the point that so many plants have failed to realize, so that they have been forced to shut down for lack of material. The length of time that excavation work can take place varies with the location of each deposit and due regard must be paid to the climate of the locality.

MECHANICAL EXCAVATING AND HANDLING APPARATUS.

In most countries the peat is commonly used as fuel and the hand digging of peat is still used. The mechanical handling of peat, which originated in Germany, is only being taken up by deposits where large amounts of peat have to be excavated. Where peat is used as an industrial fuel, only mechanical excavating and handling apparatus can be considered. There are two possibilities of opening up a peat fuel deposit or peat bog; namely, the operation of excavating a dry peat bog and the excavation of peat from an undrained swamp.

In the first case that part of the deposit which is to be used is drained, generally by preparing small ditches which lead into a main ditch. The deposit is then cleared and leveled so that the surface can be used as a drying ground. These ditches should not be too deep and should not go beyond the depth of the deposit to prevent in the latter case contamination with mineral substances. It is often necessary during the winter season to allow the water to accumulate in the deposit and in case the deposit takes fire it can be quenched by allowing the water to rise in the ditches.

The machines used for excavating the peat are generally of the simplest form of construction and are similar to those used ordinarily in ditching and digging. The modern tendency in using power ditching machines corresponds to the types of side chain and bucket excavators, which are very effective in peat which is well decomposed, but cause trouble in poorly decomposed deposits on account of tree stumps which have not yet disintegrated. These machines generally work from the side of the ditch, which has the advantage of mixing the peat from the different depths and thereby securing a homogeneous product. On account of the high cost of labor in this country the peat excavated, even in small plants, is found to be done more economically by machines than by hand digging. The steam shovel has also been used in this country and gives satisfactory results. On account of producing homogeneous material and the ability to spread the material more easily on the drying ground, the chain and bucket excavator seems to be most favored.

DIFFICULTIES TO BE OVERCOME.

In devising machines of this nature not only has the ability of excavating efficiently to be taken in consideration but also the expense and labor incurred in handling the material after it leaves the excavating machine. As peat deposits will not hold a very great weight per square foot, thought has to be given properly to mount the machine so that the weight is distributed as uniformly as possible. The machines are generally mounted on cars having wheels with very wide treads, which have on some deposits, even then, to be supplemented by timbers. The more modern machines are provided with caterpillar tractors, which have proved very satisfactory in this kind of work. Where possible these machines are operated by electricity, otherwise the power plant has to be installed on the machine. However, this should be obviated as far as possible on account of the possibilities of setting fire to the deposit during the dry season. Peat fires can become very disastrous and are often very hard to put out.

NO STANDARD PEAT DIGGING MACHINES.

There are no standard peat digging machines in this country, and generally in each case they have to be designed to meet the local conditions. These machines have to be of an efficient form and provided with a hopper for receiving the peat which falls into a cutting or macerating trough, thus pulping the peat and cutting up its strands. These macerating machines are provided with screw conveyers and on the

same shaft can have knives for cutting up the fibers, while other machines have sections provided with both fixed and movable knives which work together like the blades of scissors.

After the peat has passed through the above-mentioned machinery, it is then spread on the drying grounds, which is generally the surface of the deposit, and here exposed to the sun and wind. Every once in a while a new surface of this layer is exposed and eventually the material is scraped together and hauled to the plant. By this method peat originally containing 80 to 95 per cent water can be dried down to 25 to 35 per cent water right on the field, and this moisture content is low enough where peat is used in gas producers, but for cases where it is used for making steam direct it should be dried down to about 5 per cent water, although 20 per cent is frequently used; in a large power plant this can generally be accomplished at the plant, where enough waste heat exists to reduce the moisture content economically.

In excavating an undrained deposit the machinery has to be mounted on a barge or float and either a dipper-dredge or pumping system is used. Both of these systems are satisfactory; their use depends entirely on the local conditions, quantity of peat to be handled and its stage of decomposition. In each case, however, the peat has to be handled on drying grounds after it leaves these excavating machines. Highly decomposed peat can be very efficiently handled by pumping if very little fibrous matter is present in the deposit.

COSTS AND METHODS OF BURNING PEAT.

The cost of excavating and air drying peat governs the success or failure of a peat fuel plant. All the cost involved in handling the peat from the deposit to its storage pile should not exceed $1.30 per ton of theoretically dry peat. The cost depends very much on the size of the excavation plant and on the climatic conditions. My experience in excavating peat covers a cost ranging between 25c and $1.30 per ton of theoretically air-dried peat on the field. It is seldom that the excavation price exceeds $1 per ton of peat, the average being in the neighborhood of 75c. per ton of theoretically dried peat.

In producing power from peat we have available the same methods as are now used for coal, either firing peat direct under a boiler for raising steam or gasifying it in gas producers and using the gas in gas engines or under boilers and in furnaces. Where industrial power is produced from peat, it is necessary to locate the power plant at the edge of the deposit or in very close proximity thereto. The reason for this is that the handling of large quantities of peat fuel involves several problems of a serious nature; on account of its bulkiness and low heating value, compared to coal, it necessitates handling larger volumes and burning an appreciably larger quantity than is the case when coal of a good quality is used for raising steam. Furthermore, very large stocks of peat fuel have to be held, and the sensible heat contained in the flue gases, together with exhaust steam, is used to advantage in reducing the moisture content of the air-dried peat. Peat fuel generally burns freely to a fine, easily handled ash. Thus it is practically totally consumed and the handling of the ash is reduced to a minimum.

ANALYSIS OF GOOD PEAT FUEL.

An approximate average analysis of a good peat fuel is as follows:

	Per Cent
Volatile matter	60
Fixed carbon	30
Ash	8
B.t.u., 8,500	

When peat fuel is burned direct on a grate it is necessary that not too much fine material is mixed in the lumps and it is therefore frequently advisable to briquet the peat before using it for such purpose. Many peats have enough binding material present in them and others will not hold together at all unless mixed with pitch or similar material. In making machined peat it is advisable to form the bricks while the peat is still plastic and then let them dry. Some peat briquets form easily without the addition of any foreign binder, especially when heated up to about 100 deg. C., when the natural paraffine present will hold the peat in its form and produce briquets which are comparatively easy to handle.

REQUISITES OF BOILER FOR USING PEAT FUEL.

The points to be considered in constructing a boiler for using peat fuel are a large grate area with very small air spaces, large combustion chamber, and long travel for the flue gases; 15 lb. of peat per sq. ft. of grate per hr. has been found good in practice. Peat has a disadvantage in allowing unburned hydrocarbons and hydrogen to escape in the ordinary combustion chamber built for burning coal. It is therefore necessary to have a specially constructed combustion chamber to insure complete combustion when using this fuel. Peat has another disadvantage, because when firing with peat the fire door has to be open quite a considerable part of the time, because men cannot handle as much peat on a shovel as coal owing to its low specific gravity. However, if the peat is used as a pulverized fuel it will be found not only economical to prepare but can compete with coal more advantageously.

When peat is dried, even air dried, it does not absorb moisture from the atmosphere very readily, and even with 20 to 25 per cent moisture content it has the physical characteristics of a dried material. Provided it has been properly macerated it is very easy to pulverize and will not pack, running and behaving similarly to dried sand. With these conditions, together with its low specific gravity and high combustibility, it makes an ideal powdered fuel. Peat has been used in this way in Sweden and has shown that it is possible to obtain better calorific value than by burning the peat on a grate, and every indication points to the fact that peat fuel can be used practically and commercially for raising steam when used as a powder, so the future developments of the use of peat as an industrial steam raiser will tend to be in this direction.

COST AT WHICH PEAT CAN COMPETE WITH COAL.

The maximum cost per ton which peat fuel can stand and still compete with coal is governed by the cost of steam coal at the place where the power plant is located. There is, however, a fixed minimum cost, determined by the cost of its manufacture, below which peat fuel cannot compete with coal. Peat used directly under a boiler for raising steam can generally compete with good steam coal costing $4.50 or less per ton or $4 or less per ton when the peat is used in a pulverized condition. Above this price where peat deposits which are suitable for fuel are available, they become a serious competitor of coal. The more economical method to convert peat fuel into power is to burn the same in a producer to form combustible gases and then use gas engines or burn the gas under boilers to obtain the desired results.

Inasmuch as peat used for generating steam contains generally from 16 to 21 per cent moisture, less water is evaporated than would be the case if peat were theoretically dried. Peat of this nature directly on the grate will evaporate on an average 4 lb. of water per lb. of peat, while pulverized peat evaporates about 5.25 lb. of water per lb. of peat powder.

PEAT PRODUCER GAS.

The most economical method for producing power from peat is to convert the peat into combustible gases in a specially constructed gas producer, or if the gas contains any nitrogen to burn the same in a byproduct recovery producer. Since several of the peats examined in this country have a high nitrogen content, it would be possible to recover the largest part of this nitrogen in the form of ammonia.

The commercial use of peat in gas producers seems to have been successful in Germany and Sweden, where they have been used for several years in metallurgical operations, brick and glass making and in lime burning. Tests have been made on this continent both in Canada and at the fuel-testing stations of our Government, where it has been shown that gas of good calorific quality can be produced, similar results being obtained as in producer gas from bituminous coal. About 40 cu. ft. gas is produced from a pound of peat having a calorific value from 130 to 150 B.t.u. per cu. ft. These producers have the great advantage that peat containing as high as 25 per cent or over of moisture can be used. The most economic method of course for using this is for driving gas engines, but engines of large units have not yet proved very satisfactory in this country. In Europe they are operating and have been for a large number of years apparently with a high degree of satisfaction. It therefore appears that for the present it would be most desirable to use this gas under boilers for raising steam.

AMMONIUM SULPHATE SUCCESSFULLY RECOVERED ABROAD.

When the peat contains nitrogen, the latter is converted in the producer to ammonia, which can be recovered as ammonium sulphate and prove very profitable. There are several plants in existence in Germany, Italy, Holland and France where the Mond producer, modified by Lihme, is working very successfully. In these producers, gas of about the same quality and quantity as described above is obtained and in addition thereto about 80 per cent of the nitrogen is recovered as ammonium sulphate. These producers are very useful to the peat industry inasmuch as peat containing as high as 42 per cent moisture can be used satisfactorily. In Germany peat containing 50 per cent water and 1.05 per cent nitrogen has been operating for eight years or more delivering a gas of 150 B.t.u. and producing 70 lb. of ammonium sulphate per ton of theoretically dried peat. The nitrogen content of the Italian peat is 2.3 per cent and they recover 215 lb. of ammonium sulphate per ton of theoretically dried peat.

Previous to the war the peat was excavated, dried and conveyed to the producers at a cost of 60c. per ton of peat (theoretically dried). In an ammonia recovery producer the ammonium sulphate obtained will generally cover the total cost of the peat and also the maintenance and operating expense of the gas plant, and even then show a profit. When peat has to be converted into combustible gas it is very easy for a power plant to take this gas and use it for raising steam or generating power by direct explosion in a gas engine. The gases from a peat producer are composed on an average of 20 per cent carbon monoxide, 9 per cent carbon dioxide, 1 per cent ethylene, about 4 to 5 per cent methane and 6 per cent hydrogen; while an average gas from an ammonium recovery producer contains 10 per cent carbon monoxide, 20 per cent carbon dioxide, 20 per cent hydrogen and 5 per cent methane. The building of large gas engine units to use low power gases cannot be an impossibility. Since this has been achieved satisfactorily in Europe, our American power engineers must make up their minds to design an efficient engine of this type, else they will have to be imported from Europe. The power engineer can easily realize from the figures given that we have here an economical and cheap source of power, but it must be realized that economic results cannot be obtained unless large installations are designed and that our capitalists must be willing to break a new patch in developing and utilizing a resource so easily obtainable.

CONCLUSION.

There is no difficulty whatsoever in either using a peat for steam raising as a powdered fuel or using a peat in a gas producer. The difficulties, or better the failings, in producing peat as a source of fuel lie in the lack of attention which has been paid to the excavation and drying of the same and the poor engineering ability which has tried to overcome these troubles.

RUNNING MARTIN FURNACES WITH COLD COKE OVEN GAS.

Fr. Springorum reports on recent attempts carried out at the Hoesch Steel Works to heat Martin furnaces with cold coke-oven gas.

The experiments were started in 1913. A 30-ton furnace, heated with producer gas and fitted with ordinary ends, was altered according to März's suggestions and heated with coke-oven gas. These attempts having proved satisfactory, a second 30-ton furnace was laid down in 1913, while in 1914 three 100-ton furnaces were installed in the new Martin steel works to run off coke-oven gas. As regards the modifications made in the furnace for the new system of heating, mention may be made of a new wrought iron water-cooled tuyère 120 mm. diam. which was built in for conducting the gas to the hearth space. The tuyères have proved very satisfactory. Experience in working has shown that the calorific value of the gas is the deciding factor as regards the economy of the method. At the outset this value was 4,300 to 4,500 large calories, the gas consumption working out at 300 m^3 per ton of steel produced. In this connection the larger furnaces were more satisfactory than the small ones.

The duration of a 30-ton heat was 5 to 6 hours, and of a 100-ton heat about 9 hours. Later on, the extraction of benzol and other factors caused the calorific value to deteriorate and it fell to 4,000 cals., the duration of heat rising accordingly. In the case of the 30-ton furnace, melting at a calorific value of 3,800 cals. was uneconomical, whereas the larger furnaces were less sensitive.

Considerable hearth space is required for the perfect combustion of the coke oven gas, as the velocity of admission is high and the fine jet of coke oven gas must first of all be expanded by heat so as to mix thoroughly with the air.

The writer indicates the following advantages attendant on heating: Coke oven gas is anhydrous and poor in sulphur, so that it is possible owing to the high hydrogen content easily to provide a reducing atmosphere over the bath, which is of great advantage in the production of high-quality steel for preventing excessive oxidation and decarburization. The manganese consumption is lower throughout than when working with producer gas. Coke oven gas burns with an almost invisible flame, so that the whole bath can easily be inspected. In addition, a saving was effected in refractory bricks, in wages and steam; and, further, running on producer gas can be entirely excluded.—*Stahl und Eisen*, Jan. 1, 1920; *Zeitschrift des Vereines deutscher Ingenieure*, Jan. 24, 1920. Abstracted by *The Technical Review*.

METHODS OF DRIVING BLOWERS IN STEEL WORKS.

This article, of which the present conclusions form the final instalment, discusses the relative merits of different kinds of drive for blowers in view of present day conditions.

In arriving at any estimate of the cost of running, the two factors should be considered, viz.: (*a*) the price of coal will be much higher than pre-war prices for a long time to come; (*b*) all large steel works in Germany have turned over to 3-phase current for power transmission. The author therefore thinks the blower of the future will probably be either (1) driven direct by the gas engine; or (2) by a three-phase motor supplied by current from the gas generating station.

The assumption that with electrically driven blowers a motor of the same power will be necessary as would be required with the direct-driven blower is wrong, as a blower drive is of an intermittent character in which no-load, hot-blowing, charge-blowing and intensified blast alternate. The author cites an actual example of a blower operating in a certain works, and gives figures which show that the power station will, on an average, have to allow for a load of one-half more than the consumption of the blower.—*Zeitschrift des Vereines deutscher Ingenieure*, Jan. 17 and 24, 1920. Abstracted by *The Technical Review*.

Three New Sources of Fuel Alcohol*

Production of Alcohol from Molasses, Wood Waste and Acetylene

GERMANY which, prior to the war manufactured alcohol only from potatoes and grains, when compelled by the Allied blockade to conserve its food supplies, resorted to different methods of alcohol production, some of which were formerly commercially impractical and others entirely unknown in that country. These include the following processes:

a. Process based on the use of molasses.

b. Process utilizing the sulphite liquor of plants for the purification of wood pulp.

c. Process consisting in saccharifying wood and fermenting the sugar thus produced (grain alcohol from wood).

d. Process of generating alcohol by the hydrogenation of acetic aldehyde, which in turn is obtained by fixing the element of water on acetylene (carbide alcohol).

The German government assumed full charge of alcohol production, and it was feared in the industry that this step, which was taken as a war measure, would not be rescinded, but would result in an alcohol monopoly in the future.

This project of an alcohol monopoly was adopted on its third reading by the Reichstag, on July 13, 1918, by the Bundesrath on July 19, and finally promulgated as a law on the 26th of the same month.

In the text of this bill is found some very interesting information on the new processes (b, c and d) referred to in the foregoing. There is no need to refer here to the fiscal character of this law, but the technical appendices will be of interest to our readers, and a translation is here given. Aside from the technical information contained therein, these appendices furnish general indications regarding the economic values attributed to the different methods at the time.

In cellulose plants, the wood pulp is boiled in an aqueous solution of bisulphite of calcium, in order to purify the cellulose contained in the wood, by the elimination of materials with which it is impregnated. Up to quite recently, this bisulphite solution, after it had once served its purpose, was not recovered, but was drained off and often caused great damage.

During the early part of 1900 it was discovered that the waste liquors of German cellulose factories contained a little more than one per cent of sugar, and it was found that from 1,000 cu. ft. of this waste liquor it was possible to recover from 42.5 to 50 gal. of alcohol. These results were verified in 1915 by renewed experiments. The discovery, however, was never put to practical use in Germany, for the reason that the manufacture of alcohol from sulphite waste liquors—in view of the fiscal regulations concerning alcohol then in force—would have yielded no profit. Moreover, the often expressed belief that by the treatment of the sulphite waste liquors for the production of alcohol (that is to say, by the elimination of the sugar content), the delicate question of waste liquor disposal would be solved, was not a sufficient incentive. In Sweden, on the other hand, the manufacture of alcohol from waste liquors was successfully taken up during the year 1909, and in that country there are now numerous plants for the production of alcohol from sulphites.

Under the compelling influences of the war the manufacture of alcohol from sulphite waste liquors was taken up anew in Germany, and the experience gained in Sweden was turned to good account.

The process for recovering alcohol from sulphite liquor comprises three operations, as follows: (1) The preparation of the waste liquor for fermentation; (2) the fermentation of the sulphitic must, and (3) the distillation of the fermented sulphite solution.

Sulphite waste liquors contain, in addition to sulphurous acid, which interferes with the fermenting action of the yeast, acetic acid and formic acid. These acids are eliminated partly by blowing air through the waste liquors, after they have been raised to a temperature of 185-195 deg. fahr., partly by the addition of carbonate of lime and of a little slacked lime. The neutralization must be carried to a point necessitated by the subsequent fermentation. This is accomplished in concrete tanks in which the waste liquor is allowed to remain for some hours in order that it may become clarified. This is followed by another clarification of the liquor from which the mud has been separated, which is accomplished in a reservoir which serves for filling the fermentation vats. The waste liquor is then transferred to a concentration tank cooled by air, in which at the same time it is cooled, saturated with air and concentrated to a certain degree.

Fermentation takes place in tanks of 3,500 cu. ft. capacity, with the aid of a very active yeast, which has been slowly accustomed to the conditions which the fermentation of the waste liquor presents, and which is continually transferred from a tank in which fermentation has been completed, into a fresh tank. The sulphate waste liquor contains insufficient quantities of nutriment for the yeast, and for this reason there is added either ammonium sulphate, or super-phosphate, or, on the other hand, a yeast extract which is prepared in distilleries with waste liquor containing an excess of yeast. The fermentation takes place at 84-85 deg. fahr., and on the average requires 72 hours, producing from 66-72 gal. of alcohol from 1,000 cu. ft. of waste liquor.

The alcohol contained in the fermented waste liquor is eliminated in large distilling apparatuses, in which, on account of the small alcohol must content (0.9 to 0.95 per cent), and on account of the large quantity of liquid to be treated, the application of heat is especially advantageous. The must contains volatile, organic acids, and filters of sodium carbonate must be introduced during the distillation. The distilling apparatus may also receive a charge of a solution of sodium carbonate.

In some plants, the unrectified alcohol obtained from bisulphitic waste liquors still contains a small amount of sulphuric acid. The only thing to distinguish it from unrectified alcohol obtained from potatoes is the small content of methyl alcohol and of aldehyde. Small quantities of fusel oil are also often found in it. The crude alcohol is materially improved by the use of distilling apparatus working on the principle of separating the head, in such a way as to obtain, by the separation of the heads (representing 10 per cent of the total) a sulphite alcohol susceptible of being denatured and the heads purified.

The purification of sulphite alcohol does not present any special difficulty. It should be pointed out, however, that rectified sulphite alcohol still contains a little wood alcohol which can be separated from it only with difficulty. Sulphite alcohol may be employed for all purposes for which potato alcohol is suitable.

If we assume a yield of 10.7 gal. of alcohol per ton of cellulose (which corresponds to 0.9 per cent of alcohol in the fermented liquor), the German sulphite distilleries with the plant installed by them during the war, in one year can furnish 116,000 hectoliters (3,000,000 gal.) of alcohol (corresponding to 1,044,000 metric quintals, or nearly 100,000 tons of potatoes). The total production of the cellulose works working the sulphite process being approximately 600,000 tons per year, in peace-time, by the treatment of all the waste liquors for the production of alcohol, it would be possible to obtain annually

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6,400,000 gal. of alcohol (representing a consumption of 240,000 tons of potatoes). Whether the cellulose factories will extend their alcohol production will depend upon what progress is made with other methods of utilizing waste liquors. The small cellulose works, which during the war could work part of their waste liquors for the purpose of producing glues, did not consider it of sufficient importance to erect plants for the production of alcohol.

COST OF PRODUCTION.

The cost of producing alcohol from sulphite is still undetermined. A diminution of the cost will not be possible until after the fruition of efforts looking towards the concentration of the vinasse derived from the emptying of the sulphite must, and toward the production of methyl alcohol, acetone, acetic acid, and cellulose wax by the dry distillation of this vinasse.

From the remotest antiquity, alcohol has been obtained from the saccharine juices of plants, and from vegetable material containing starch. Experiments with the object of preparing alcohol from cellulose—the carbo-hydrate of the greatest importance next to sugar and starch—were attempted only at a relatively late date. In 1819 it was found possible, by treating cellulose by means of concentrated sulphuric acid, to obtain a fermentable sugar, dextrose. The production of alcohol from the cellulose contained in wood seemed at first an insoluble problem, in spite of numerous researches. Not only does the need of large quantities of sulphuric acid for the transformation of the cellulose into sugar occasion heavy expense, but it also involves great technical difficulties, which are due to the fact that it is necessary to separate the acid from the dilute saccharine solution.

Since 1890, chemists have paid renewed attention to the problem of obtaining alcohol from substances containing cellulose, as is evidenced by the numerous patents issued on the subject during that period. The latter generally relate to the transformation of cellulose, under the influence of a dilute mineral acid, and the majority effect the process in close vessels under pressure. Attempts have been made to saccharize the cellulose contained in peat, either by heating it for a long period in contact with an acid at atmospheric pressure, or by heating it for a short time in contact with an acid under high pressure. The saccharine solution obtained by filtration must be treated with chalk in order to diminish the acidity, and then be submitted to fermentation. For the saccharization of wood and of wood waste, numerous processes have been evolved, which utilize either sulphuric acid, sulphurous acid, anhydrous sulphite or a mixture of these, with the use of steam under pressure. In all of these processes, the sugar derived from the wood should be recovered by drainage. The aqueous saccharine solution should, after neutralization of the acid, be prepared for fermentation. Undoubtedly, this process permits of a yield of 14 to 28 gal. of alcohol per ton of wood in the dry state, starting with wood waste, which up to now was burned as of no value. Nevertheless, in Germany, alcohol derived from wood has not been able to compete with alcohol from potatoes, on account of the excise tax imposed. It is for this reason that none of the attempts in Germany to manufacture alcohol from wood have passed beyond the laboratory stage. On the contrary, in France, England and the United States the manufacture of alcohol from wood has entered the domain of practice. In one plant in the United States, which is said to have an annual output of 500,000 gal., the yield varies from 15.4 to 22.8 gal. of alcohol per ton of dry material.

In Germany a beginning was made in the spring of 1916 in the manufacture of alcohol from wood, with the object of conserving the potato and molasses supply. The Classen process on the one hand, and the process of Windesheim-ten-Doornkaat, on the other, proved themselves best adapted for practical application. By the Classen process the sawdust is heated for 40 min. in rotary caldrons, with sulphurous acid, under a steam pressure of 7 atmospheres (313 deg. fahr.). The steam is then allowed to expand as rapidly as possible, and the saccharized wood must is emptied out into diffusers. The saccharine solution obtained by diffusion is neutralized up to the necessary point in tanks containing an agitator, an addition of table salt is made, and the mass is allowed to ferment in fermenting tanks with pressed yeast, or beer yeast. The alcohol formed is separated in the usual distilling apparatus. With the Classen process one may count on a yield of at least 14.5 gal. of alcohol per ton of dry material. The process has been improved, so that the yield already has been increased to 20 and 25 gal., and it undoubtedly will be still further increased.

By the Windesheim-ten-Doornkaat process, sawdust is heated with diluted hydrochloric acid in the presence of catalizers (metallic salts), in rotary caldrons, under a pressure of 7 to 8 atmospheres (330-340 deg. fahr.) for 20 to 30 min. The final treatment of the saccharized sawdust is the same as that already described. This process, which is probably subject to improvement, yields a minimum of 7.2 gal. of alcohol per 1,000 lb. of wood in the dry state.

The alcohol production plants under construction will work according to these two processes. The choice between the two will depend upon the kind of acid most available, and upon the alcohol yield which will be obtained. Germany produces from 500,000 to 1,000,000 tons of sawust, susceptible of being treated for the manufacture of alcohol. The alcohol factories possess a total of 51 caldrons capable of handling one ton of dry material each. By working day and night, each caldron can handle 10 batches of material daily, or—figuring on 350 working days a year—3,500 batches yearly. That is to say, working to full capacity, it will be possible to treat 178,500 tons of wood annually on the dry basis, or 238,000 tons of sawdust. If one figures on a yield of 14.4 gal. of alcohol per ton of dry material, a total production of 2,570,000 gal. of alcohol per year is arrived at, which is equivalent to the yield from 106,000 tons of potatoes. If the yield can be raised to 24 gal. of alcohol per ton of dry wood, as is to be expected, the production of alcohol will amount to 4,190,000 gal. (corresponding to 176,000 tons of potatoes).

It is still impossible to give any data regarding the cost of producing alcohol from wood. It is certain, however, that it is much higher than that of alcohol from sulphite. The production of alcohol from wood can become commercially practical only if the wood acted upon, when deprived of its sugar, can be utilized as feed, or rather if it should prove possible to obtain from it acetone, wood alcohol and other products of dry distillation. The necessary research work has not yet been carried out, and at present the only use that can be made of the heat value of the residue of the saccharized wood, is to use it as fuel under the boilers in the alcohol plants.

The unrectified alcohol obtained from wood contains as impurities small quantities of aldehyde, wood alcohol, "furfurol" and fusel oil. The rectification of the alcohol, however, presents absolutely no difficulties. Inasmuch as the raw alcohol made from wood, on account of its low alcohol content, cannot be denatured, and therefore cannot be employed for industrial uses, purification readily yields an alcohol which is sufficient for the requirements of powder manufacture. It is still necessary to determine experimentally whether the recovery and commercial utilization of the byproducts, such as furfurol, will not permit of reducing the cost of producing alcohol from wood.

MANUFACTURE OF ALCOHOL FROM CALCIUM CARBIDE.

When lime and coke are heated to the temperature of the electric furnace, about 5,000 deg. F., a new chemical compound is obtained—calcium carbide. Of all the numerous carbides known, the carbide of calcium is industrially of by far the greatest importance, and for this reason it is gen-

erally called simply carbide. It is decomposed by water, forming acetylene, with a residue of lime. If acetylene is introduced into a heated, diluted acid, in the presence of a mercury compound, aldehyde (acetaldehyde) is formed, the components of water being fixed upon the carbide. Aldehyde is a very volatile combustible liquid, of penetrating odor, which combines with hydrogen in the presence of certain metallic catalizers, such as nickel, producing ethyl alcohol (grain alcohol).

As the acid used and the mercury compounds or other metallic catalizers are not modified in the process, or in any case are capable of being returned to their initial state with only small loss, and as the hydrogen may be produced with coke and water, this method of manufacturing alcohol requires only coal, limestone and a rather small amount of heat.

In the manufacture of alcohol from carbide, the following expenses are incurred: 1—Manufacture of carbide; for 1,000 gal. of alcohol it is well, in the present state of the art, to count on approximately 6.5 tons of carbide, for the production of which 24,000 kilowatt hrs., 8 tons of coal and 12 tons of limestone are necessary. If cheap power is obtainable in the neighborhood, as, for instance, water power, or power obtained from cheap fuels, such as lignite and peat, the cost per kilowatt-hour may be as low as 2 pfennigs; in that case, the power cost for 1,000 gal. of carbide may be set down at 240 marks. The cost of the raw material, charcoal and limestone, is approximately 60 marks; the cost price of carbide previous to the war in Germany was 112 to 115 marks per ton. Experience indicates that these figures represent the lower limit, and this statement is corroborated by the figures previously given. As far as can be judged at present, small plants, or those not favorably situated, could not produce at this figure. What the price of carbide may be after the war can only be conjectured. It should be pointed out, however, that the cost of packing for the retail trade, which must be of such a character as to prevent all moisture from reaching the carbide, which cost is not appreciable, need not be considered here, and that the overhead expenses connected with the manufacture of carbide at wholesale need not play a very important part. Moreover, the amount of 2 pfennigs per kw. hr. does not seem to be the minimum at which power can be delivered in Germany.

2—The manufacture of acetylene from carbide does not involve any special expenses for other raw materials, for the decomposition of carbide is effected by means of water, and the purification of the gas is effected by different purifying masses of which some are cheap in themselves, while others are capable of being regenerated, among these latter figuring compounds of copper, chrome and lead, as well as of chlorine and lime. The yield to be expected is 80 gal., equivalent to 0.35 lb. of acetylene per pound of carbide of good quality.

3—The following operation, that is to say, the transformation of acetylene into aldehyde, does not involve the consumption of any important amount of raw material, but does involve the consumption of a large amount of energy. Up to the present, it involves only slight losses. The yield, according to information furnished by the plants (of which none has been in operation for any great length of time) is at most 90 per cent.

4—A most important item in the final operation, the production of alcohol, is the consumption of hydrogen. In order to obtain 1,000 gal. of alcohol, it has been calculated that it is necessary to consume at least 53,000 cu. ft. of hydrogen, which can be obtained at about 2.25 marks per 1,000 cu. ft., this low price being made possible by the low cost of the raw materials, in spite of the expensive installations necessitated for production and purification.

Assuming that all conditions are favorable, that is to say, that the location of the plant is wisely chosen, and that operations are conducted on a sufficiently large scale, one may count on a cost price of 900 marks per 1,000 gal. of alcohol, equivalent to 90 pfennigs per gal., this including the cost of raw materials. To this must be added something for depreciation of plant, salaries, etc., items which are rather difficult to estimate in advance. The purification of the alcohol obtained should not present any greater difficulties than the purification of alcohol obtained by fermentation. As a result of the method of preparation, it does not contain any secondary product of fermentation known under the name of fusel oil; on the other hand, it may contain some sulphuric, phosphoric and arsenic combinations and certainly there will be aldehyde and substances derived therefrom. The best samples so far presented to the government represent a fine industrial alcohol which can be used in most industries.

PRICE CALCULATION.

The preceding price calculations are confined to a certain extent by the conditions of a contract under which a Lonza (Switzerland) concern has engaged to furnish alcohol obtained from carbide to the Swiss government. The price of the rectified alcohol, according to the contract, is to be 1,330 marks per 1,000 gal., the Federal administration taking delivery at the plant in its own tank cars. From a certain point of view, the operating conditions of the plant at Lonza should be better than could generally be obtained in Germany. Undoubtedly this plant gets its power at less than 2 pfennigs per kw. hr. Near the great waterfalls in Norway, there are large plants which obtain power at approximately 0.5 pfennig per kw. hr. On the other hand, the contract was closed on the basis of high cost of coal (36 marks per ton). The cost price of the Lonza plant (which is a private enterprise) may be estimated at a little more than 110 marks per 100 gal. of alcohol.

It should not be lost sight of that such calculations are subject to numerous causes of error, which are difficult to estimate. If, for instance, the cost of the kw. hr. becomes greater than that previously given, as may easily happen in certain parts of Germany, if the yield of aldehyde or alcohol is a few per cent less than that assumed, or if the renewal of the carbide furnaces occasions greater expense than that provided for, and, finally, if the royalty to be paid on the patent is added, the cost price of alcohol from carbide may come somewhat higher than that arrived at above. A private corporation, which has carried on experiments on a small scale, has reached the conclusion that alcohol derived from carbide cannot easily compete with alcohol of fermentation, even if taxation should be the same.

The process outlined above is so far the only one which has been applied on a large scale. However, it is not the only one theoretically possible. One may also conceive of a process in which no aldehyde is produced, but only ethylene, by the addition of hydrogen to the acetylene. It is an easy matter to pass from ethylene to ethyl alcohol, by a process which has been known for a long time. This has recently been more closely investigated, but it is not yet possible to give any information regarding its success.

Plants already in existence in Germany for the manufacture of carbide and those whose construction has been decided upon, will furnish annually from 400,000 to 450,000 tons of carbide, when operating to full capacity. After deducting the quantities of carbide necessary for lighting, for metallurgical operations, etc., there remain nearly 400,000 tons for fertilizer or for alcohol, and this would produce 66,000,000 gal. of alcohol.

It remains to be investigated what influence the calcium cyanamide obtained from carbide may have on the production of potatoes, and thus on the production of alcohol.

One pound of carbide when heated with nitrogen furnishes 1.25 pounds of calcium cyanamide, containing approximately 20 per cent of nitrogen, and considering that it is customary to count on a gain in yield of 100 pounds of potatoes per

pound of fixed nitrogen in the fertilizer, the use of one pound of carbide for the manufacture of nitrogenous fertilizers would result in a gain in production up to 25 pounds of potatoes, equivalent to 0.133 gal. of alcohol; that is to say, more than four times the amount of alcohol which may be obtained directly by chemical process.

On the other hand, if one considers that calcium cyanamide is now the lowest priced fertilizer, and that the growing of potatoes usually has a very favorable effect upon the following other crops, the direct manufacture of alcohol from carbide cannot be considered seriously until the agricultural demands for nitrogenous fertilizers in Germany have been satisfied in some other way, and filled at an adequate price. On the other hand, it is possible that there will not be a demand for a long time for all of the fertilizer that can be produced by the German plants utilizing carbide. Calcium cyanamide has this disadvantage that the caustic dust is very annoying when it is being spread, and that its fertilizing action depends, more than for other nitrogenous fertilizers, upon the nature of the soil, the atmospheric conditions, the nature of the plant, and the method and time of use. The German demand for nitrogenous fertilizers in the next few years may be estimated at between 1,500,000 and 2,000,000 tons per year. The yield in ammonium sulphate of the German coke ovens may be estimated at approximately 500,000 tons, and this may be increased. In fact, it is likely that the production of ammonium sulphate at the coke works will be increased to 1,000,000 tons within a few years. Whether it will be possible readily to sell from 500,000 to 600,000 tons of fertilizer, in the form of calcium cyanamide, will depend in the first place upon the price, and also upon the competition created by the importation of saltpeter from Chile, and from Norway, and other fertilizers which are technically perhaps even more advantageous. Under the first head, we have to do here with ammonium compounds, and with their derivates prepared by the Haber process, the entire supply of which at the present is under government control. If the nitrogenous fertilizers, which are relatively cheaper than those obtained from carbide, should be set free again, the result would be that the large German factories of carbide and calcium cyanamide would have to look elsewhere for a market for their products.

SELECTIVE ABSORPTION AND ITS RESULTS.

VARIOUS investigators both in this country and abroad have been recently engaged in studying the curious phenomenon known as selective absorption. The results of their researches are interestingly summarized in *La Revue Générale des Sciences* (Paris), as follows:

It is a well-known fact that various colloids absorb the free base of the salts dissociated by hydrolysis in their aqueous solution more rapidly than the acid. They redden litmus by absorbing the blue base. In a solution of a blue salt whose free base is red these colloids absorb the red base and acquire a red color meta-chromatically.

Basophilous colloids are found in histological compounds such as cotton fibers and pectic membranes and in cytological compounds; they also occur in soils (in clay and in humic substances) and likewise in deposits of baregine, etc. The so-called acid earths owe their property of reddening litmus paper at least in part to basophilous colloids, includ- the humic substances, clays, silicates, and oxides of iron. The basic jellies on the contrary, which include the oxides of zirconium, thorium, aluminum, lanthamium, zinc, beryllium Be iron, and chromium absorb the acid of the dye known as Congo red; when they are heated in the presence of a solution of Congo red they exhibit the red color characteristic of salts (6). This explains why thermal waters (the waters of Barèges) restore upon boiling the red color of solutions of Congo red which have been turned blue by acids, with a precipitation of the *insoluble blue acid* which is an isomer of the red acid of the Congo.

By reason of their power of selective absorption certain colloids are capable of being employed as reagents for analytical purposes, being capable of separating the different ions of electrolytes in solution and of isolating certain substances which it is very difficult to isolate chemically. In living creatures we may explain by the theory of a selective absorption which varies in accordance with metabollic conditions, why it is that the nuclear chromatine sometimes fixes the blues (basophilous nuclei) and at other times the reds (acidophilous nuclei).

In nature there occurs "a struggle for bases" between the basophilous colloids of plants and those of the environment: thus the basophilous Zoögleae of the baregines demineralize thermal waters; the Diatoms (*Synedra*, etc.) possess beneath their siliceous shell a thin membrane, which is capable of fixing metallic bases even upon the living creatures; many absorbent hairs come in contact with the soil by means of a basophilous pectic membrane. Finally, the tissues which succeed in reacting successfully against parasitic infection exhibit a marked basophily which it is possible may oppose the migration of the bases of the host into the parasite.

The mediums which retain bases strongly, acid soils, will support only forms of plant life which are especially adapted to them, such as the *Vaccinium corymbosum*, etc., unless bases be added to them in the form of lime in excess of their basophilous power of absorption.

ARTIFICIAL DAYLIGHT.

AN English artist and designer, Mr. George Sheringham, recently exhibited before the Society of Illuminating Engineers, in London a remarkable device for producing the exact effect of daylight, a problem which there have been many efforts to solve. His apparatus aroused much interest and was extremely successful in producing the illusion of white light.

The apparatus itself consists of a large shade on whose under surface is a design in colors carefully worked out to agree with a definite mathematical formula governing the proportions. Upon the surface thus colored the light from an electric bulb is projected in such a manner that all the rays strike the shade and are diffused into the surrounding atmosphere. The transformation into white light or "daylight" thus secured is made possible by the skillful choice, proportion, and arrangement of the various colors employed. By this means the excess rays from the red end of the spectrum are absorbed, and *apparently* (so far as the sensation upon the optical nerve is concerned) the rays towards the violet end, which are ordinarily deficient in artificial light.

Mr. Sheringham first constructed the apparatus in a very simple form and employed it for his own studio work in the fall of 1918. Some time afterward it was exhibited to Major Klein, advisor in the physics of color to the Calico Printers' Association of England, and former chief of the experimental department of the British Camouflage School. Major Klein was at once struck with the potential importance of the invention with respect to all those industries such as dyeing, painting, frescoing, etc., which employ color. He realized, however, that the apparatus could not be definitely accepted until it had been scientifically tested, adjusted, and improved. He, therefore, called on Mr. L. C. Martin of the Optical Department of the British Imperial College of Science for assistance in perfecting Mr. Sheringham's invention. The success of these two collaborators in rendering the original device more effective is generally conceded by all who have seen it in operation. Whereas blues and greens seen by an ordinary incandescent light have their intensity diminished to about one-ninth and one-half respectively, under the Sheringham light they shine out as brilliantly as the reds. Delicate shades of grays and blues are easily perceived and navy blue shows in its true color instead of looking black. A point which will be of special interest to artists is that tones of yellow very elusive to ordinary light can be as readily distinguished as in bright daylight.

Electric Starting Systems for Automobiles

Various Ways in Which Electric Motors and Generators are Employed in Modern Motor Cars

By F. C. Barton

EVER since the early development of the explosion or internal combustion engine, it was realized that the inherent drawback to the use of this type of prime mover lay in its inability to be started by energy stored within itself. The problem of starting the engine with the least expenditure of human energy has therefore occupied a large place in the minds of designers, with the result that various forms of starters were devised.

There were straight mechanical devices employing springs or their equivalent to give the initial impulse; then, too, there were devices in which the internal combustion engine by the use of special distributor valves was converted into a compressed air engine, taking air under pressure from a storage flask. This flask was in turn charged by some form of pump connected to the engine and driven by it during periods of normal operation. There were gas devices in which an explosive charge of acetylene, or other gas, was introduced through suitable distribution valves directly into the cylinders and was there exploded by the usual electric ignition.

Almost without exception these devices lacked reliability. The springs did not store enough energy to make second and third attempts at starting in case the first failed. The air starters developed leaks and pump troubles which resulted in the slow discharge of stored air with attendant loss of starting ability. The gas starters were always "touchy" and frequently the mixture introduced for starting would not ignite when the spark was applied, and, when it did ignite, the resulting explosion was apt to be of greater violence than is desirable from a mechanical standpoint.

There were also electrical starters, which took energy from a storage battery to drive an electric motor mechanically connected to the engine, the battery being recharged by an electric generator driven by the engine during normal operation. Other things being equal, the type of starter using electrical energy acquired a tremendous advantage over all others by reason of the possibility of combining starting with the most satisfactory form of lighting, viz., that employing Mazda electric lamps. Furthermore, it might be combined to furnish energy for the now extensively used battery ignition. Hence, electric systems always include starting and lighting, and, frequently, starting, lighting and ignition.

It is not the purpose of this article to discuss either lighting or ignition systems, but to give a brief outline of the various ways in which electric motors and generators are employed in modern automobile design and construction.

Electric starting and generating sets may be divided into three general classes, as follows:

First: The single unit system in which the same electrical machine acts as both motor for starting and generator for charging the battery.

Second: The two unit system in which the motor is employed for starting only, and is not in use for any purpose except during the starting period. The generator is used only for charging the battery, and is an entirely separate unit driven independently by some means from the engine during normal operation.

Third: A combination of the two systems already mentioned. This system usually includes a single field structure and an armature having two windings and two commutators, one being employed when the machine is operating as a motor, and the other when operating as a generator.

The single unit system requires an electrical and mechanical compromise. The mechanical reduction ratio between the armature of the machine and the engine crank shaft must be such that the speed of the armature will not be dangerous when the engine is driven at speeds equalling maximum car speeds. These engine speeds may be in the neighborhood of 3000 r.p.m. or above. It is therefore advantageous, from the generator standpoint, that the driving ratio be as low as possible but, from the motor standpoint, where a high torque is required at the crank shaft, it is desirable to keep this ratio as high as possible, as the lower the ratio the larger must be the electrical machine to accomplish a given result. The electrical compromise lies between the speed at which the machine will crank as a motor and that at which it will charge the battery as a generator.

The combination-unit system employs a single field structure and a double wound armature. In this system the armature shaft is usually extended through both ends of the machine, the rear end being connected through suitable gearing to the engine fly-wheel (upon the periphery of which gear teeth are cut) during starting operations. After starting, the mechanical connection to the engine flywheel is disconnected, and the armature of the machine is then driven by means of the forward shaft extension from a suitable power take-off on the engine arranged to drive the armature as a generator at a suitable speed.

To accomplish the change-over from motor action to generator action, various automatic or semi-automatic mechanical devices are necessary. These usually consist of a manually operated gear shifting device and switch, for engaging the motor reducing gears with the flywheel gear and completing the electric circuit to the motor winding, and an over running clutch on the generator drive which permits the armature to rotate free from the generator drive while it is running as a motor cranking the engine, but which will cause the armature to be driven by the engine when the starting gears are disengaged and the motor circuit broken. This arrangement permits the motor ratio to be selected independently of the generator ratio.

The two-unit system employs a motor and a generator, the generator being driven through an ordinary coupling, or by chain or gear by the engine, the motor being connected automatically, or by a manual shift, to the flywheel gear ring during starting operation.

The means employed for making the mechanical connection between the motor shaft and the engine flywheel has been the subject of a great deal of engineering development. At this date, by far the greatest number of devices make this connection and disconnection automatically. These automatic "shifts" consist, in almost all cases, primarily of a pinion connected by some means to, or made part of, a nut which runs on a screw thread mounted on, or cut in, an extension of the motor armature shaft. When the motor circuit is closed, the armature starts to rotate, but the pinion and nut, because of their inertia, remain almost stationary. This causes the lead screw on the motor shaft to propel the pinion forward toward the flywheel in a direction parallel to the axis of the shaft until it encounters and engages with the flywheel teeth. Contact between the edges of the flywheel and pinion teeth checks any tendency the pinion may have had to acquire the rotative action of the armature, thereby causing the lead screw to propel the pinion positively to the limit of its travel. It then can travel no further axially and must, therefore, either stop the armature or rotate with it, and, being in mesh, if it rotates, it must also rotate the flywheel and thereby crank the engine. As soon as the engine commences to run by its own power, its speed is sufficiently great, with relation to that of the motor, for the pinion to be driven by the engine faster than the screw shaft is driven by the motor.

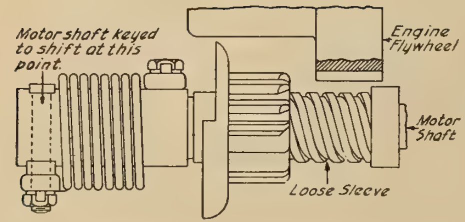


FIG. 1. SPRING DRIVE SHIFT (INBOARD)

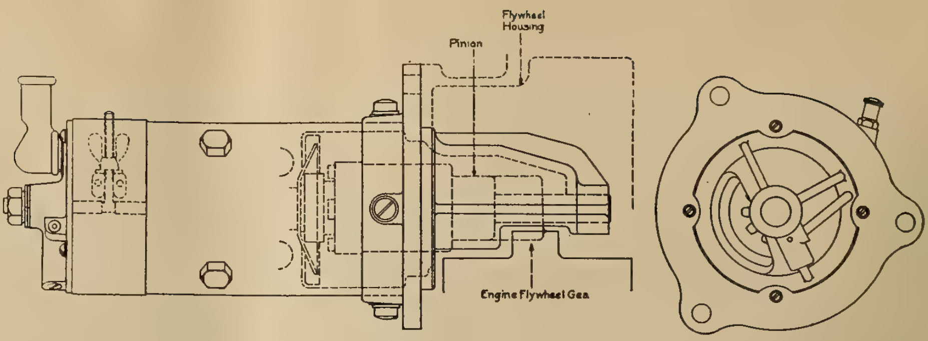


FIG. 3. STARTING MOTOR FOR OUTBOARD SHIFT

This causes the action of the lead screw to be reversed, and the pinon is therefore propelled by the engine back along the motor shaft to the out-of-mesh position. At this point the motor circuit should be broken. If it is not, it merely continues to accelerate until free running speed is reached, but as the pinion is then running at approximately the same speed as the armature, there should be little tendency on its part to re-enter the flywheel gear.

The foregoing merely outlines the fundamental actions of engaging and disengaging. A description of details, such as the method of absorbing shock, and the prevention of re-entry, and the obtaining a correct angle of entrance follow.

INBOARD AND OUTBOARD SHIFTS.

Generally speaking, there are two types of automatic screw shifts in extensive use. One transmits the torque developed by the motor to the pinion through the medium of a coil spring wound around the shaft. The other delivers the motor torque to the pinion through a self-tightening friction clutch.

The object of ether the spring or the clutch is to minimize the shock that would take place when the pinion reached the end of its travel on the lead screw on the motor shaft, or the point at which its axial motion is translated into rotative motion. It must be remembered that the rate of acceleration of the motor armature is very high, and by the time it has rotated the necessary one or two revolutions, which carries the pinion into mesh, its angular velocity is great enough to damage the gear teeth or armature shaft if the shock at the instant of starting to crank is not cushioned in some way.

These devices are also designed to minimize the liability of encountering what is known as a "butt." This means a condition where the flywheel teeth and the pinion teeth are not so lined up that they can slide directly into mesh. In

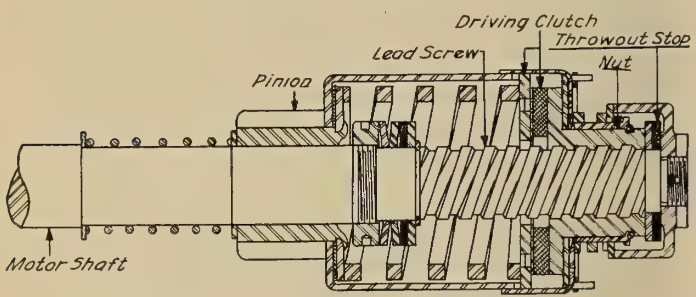


FIG. 2. CLUTCH DRIVE AUTOMATIC SHIFT (INBOARD MESH)

other words, a pinion tooth may strike end on against a flywheel tooth, and, without some flexibility in the drive, will not be able to enter, and the two will then lock tight in what is commonly known as a "jam."

To reduce further the possibility of a "jam" at the front end the pinion teeth are chamfered to produce the smallest frontal area, and still maintain a liberal mechanical margin of safety against breakage. This chamfering is very similar to that used on transmission gear teeth, where it is done for the same purpose.

The flexibility of drive also provides against another condition known as "hunting." This condition is particularly in evidence with four cylinder engines, and is a result of the reaction of gases compressed in the combustion chambers of the cylinders by the pistons on their compression strokes. The expansion of each compressed charge, on what would be the working stroke of the cycle if the charge were fired, causes the engine to tend to over-run the starting motor, which in turn tends to run the motor pinion out of mesh. The two factors which prevent this from actually taking place are the flexibility of the drive and the high rate of acceleration of the motor, which enables it to keep up with quite violent changes in angular velocity. The tendency to "hunt" decreases as the number of cylinders is increased, until, with a twelve-cylinder engine, the torque required by the engine for starting is, due to overlapping of power impulses, almost uniform throughout a revolution.

When the engine fires, causing its sudden acceleration from cranking speed to running, the motor pinion, as previously explained, is run back along the lead screw to the out-of-mesh position. This throw-out is frequently quite violent; therefore, some form of cushion stop or detent is provided at the out end of the screw to prevent the possibility of a rebound of the pinion, which might bring it into contact with the flywheel again, and, owing to the relatively high speed of the flywheel such contact might cause serious damage to the gear teeth.

Another point, which is given consideration, in "shift" design, is "angle of entrance." Normally, the pinion is approximately ⅜ of an inch away from the flywheel when out of mesh. While travelling this ⅜ of an inch along the lead screw and being restrained from turning only by inertia, a certain amount of rotative movement is acquired. Experiment has demonstrated that a definite amount of rotative movement is desirable, and reduces the liability of "butt," and that this amount is usually in excess of that which would be normally acquired; therefore, some form of friction clutch, or loading device, is provided to give "initial" friction between pinion and lead screw to give the desired number of degrees of rotation.

Two forms of each type of automatic shift are used; that in which the pinion is propelled rearward away from the starting motor when going to mesh, this being known as "outboard" mesh, and that in which the pinion in normal position is to the rear of the flywheel gear, and is therefore propelled forward toward the starting motor into mesh. This latter is known as "inboard" mesh.

Car builders who manufacture their own engines and clutch housings usually provide for inboard shift, as such changes as are necessary are purely internal matters with them, and can be easily provided for. But manufacturers of assembled cars purchasing engines and gear sets, which usually include clutch housings, almost invariably use the outboard form of shift.

The shift description has been carried out to some length, as it is a very vital part of the whole system, and, while fundamentally simple, has undergone much re-design and development to bring it to the present position of reliability and sturdiness.

STARTING MOTORS.

Starting motors are always straight series wound and of very low internal resistance, both as to windings and brushes. This is necessary to meet cold weather conditions when the battery voltage is low and the current demand is high. Under these conditions the current necessary to turn over a stiff engine may be three or four hundred amperes, which means only 3.5 to 4 volts at the motor terminals. This voltage is used up in two ways: first, in overcoming brush and brush contact drops and winding resistance, and, second, in the production of useful work. So whatever fraction is saved from the former is available for the latter, thereby improving the performance of the motor.

The conditions outlined in the preceding paragraph will be found only in extremely cold weather, but they must be met if the starting is to be successful at all times.

Fig. 4 gives characteristic horse-power, speed, and torque curves of a 4 7/16-inch diameter Bijur motor. With this curve as a base, the most desirable ratio of pinion to flywheel to give the most satisfactory cranking can be determined. It is of course to be desired that when conditions are adverse, viz., when the engine is cold, the motor speed shall be such that it will operate as nearly as possible at the peak of its horse-power curve, that being the point at which it will do the most useful work.

Take, for example, a six-cylinder engine of a size suitable for the moderate-sized car. This engine will have a displacement of 303 cubic inches or cylnders 3½ by 5¼ inches, and a flywheel having 126 teeth. We know that this engine will require about 30 lb.-ft. torque at the crank shaft to crank when hot, and that it will need three to four times that torque to crank at zero or below, and that under this severe condition the cranking speed must not fall below 50 r.p.m.

By a cut-and-try method it will be found that a nine-tooth pinion will be suitable. The ratio will be 126:9 or 14:1, or at 50 r.p.m. crank shaft will give a motor speed of 700 r.p.m. 700 r.p.m. = 8.6 lb-ft. torque or 120 lb.-ft. at engine crank shaft will take 400 amp. and deliver 1.2 h.p. which is near the peak of the horse-power curve, and, therefore, at the most desirable point. This is satisfactory for cold performance.

To find what will happen with a warm engine requiring only 30 lb.-ft. at the crank shaft or 2.12 lb.-ft. at the motor shaft, read straight up from the 2.1 torque point. It equals 135 amp., 2080 r.p.m. or 147 r.p.m. crank shaft and 0.82 h.p. which is satisfactory.

GENERATORS.

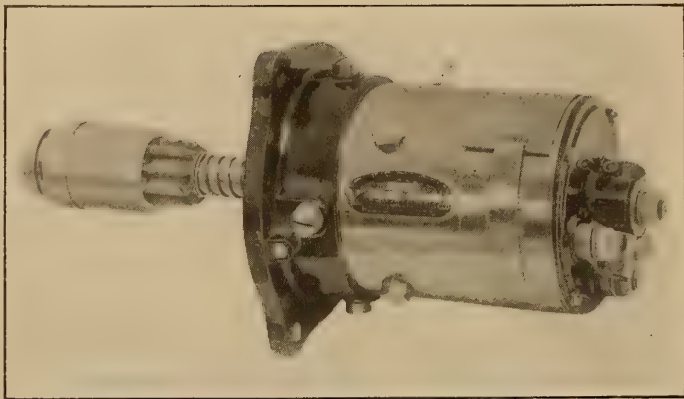
The principal factor in determining the size of generator suitable for a given car is the ratio between the driven speed of the generator and the miles per hour of the car. This factor is usually given in terms of revolutions per minute of the generator per mile per hour of the car. This is affected by:

First: the road wheel diameter.

Second the rear axle ratio.

Third: the ratio of the generator drive to the crank shaft.

This last ratio is usually determined by the number of engine cylinders, as the generator drive is in almost every instance made to run at a speed suitable for magneto drive. This would be 1:1 for four cylinders and 1.5:1 for six cylinders.



STARTING MOTOR FLANGE MOUNT (INBOARD SHIFT)

For example: A four-cylinder car having 33-inch wheels and a 4:1 rear axle ratio and a 1:1 generator to crank shaft ratio would have a generator speed of 41 r.p.m. at 1 m.p.hr. If this happened to be a six-cylinder car and the generator to crank shaft ratio was 1.5:1, the generator speed would be 61.5 r.p.m. at 1 m.p.hr.

Experience has shown that a generator to meet average conditions should delver 10 amp. at a car speed not much in excess of 14 m.p.hr. and should give maximum output at some speed between 20 and 25 m.p.hr.

The choice of a generator, therefore, is merely a matter of selecting a standard machine which will fulfill the current output conditions outlined above at the speed available at 14 m.p.hr.

Take the six-cylinder example for illustration. A generator having an output like the curve Fig. 5 would be satisfactory. This machine delivers 10 amp. at almost exactly 860 r.p.m., which equals 61.5 × 14, or 14 m.p.hr. car speed. It reaches a maximum of between 16 and 17 amp., at 1400 r.p.m. equaling 23 m.p.hr.

After the maximum output has been reached a further increase in speed causes the current rate to fall off. This falling off of the charging rate at high speeds is a most

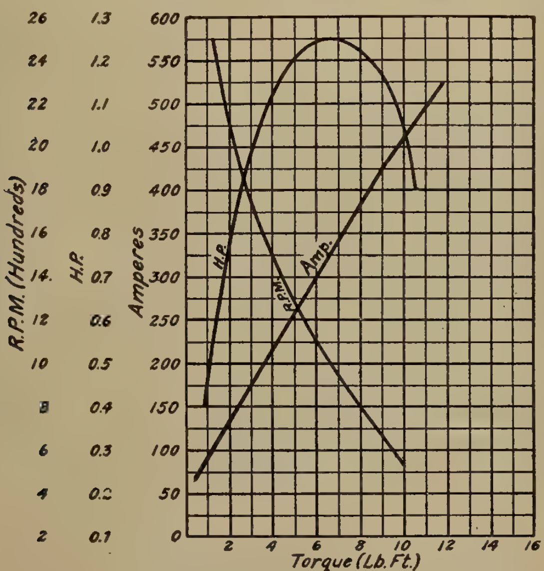


FIG. 4. STARTING MOTOR HORSE-POWER, SPEED AND TORQUE CURVES

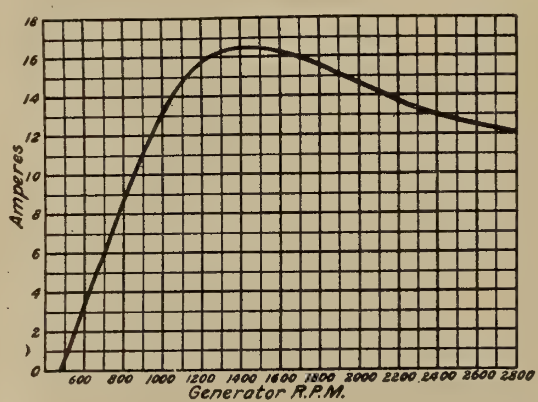


FIG. 5. BATTERY CHARGING CURVE, THIRD BRUSH GENERATOR

desirable feature of a generator employing the third brush type of regulation, as it means that the average city driver, who operates at low speeds but who uses the greatest amount of current for lighting and starting, gets the highest charging rate, whereas the tourist or country driver, operating over longer periods of time and at higher average speeds than the city man, gets a lower rate of charge which saves his battery from heating and loss of electrolyte due to the decomposition of the water when gasing.

The foregoing remarks on charging rates relate to the current regulated or third brush type of machine. This is the type most extensively used on moderate and low-priced cars. One other system of regulation is in fairly extensive use, especially among the higher-priced cars. It is the system employing voltage control. The feature of this method of control is that it supplies a high current when the battery is low, and a low current when it is high. It approximates what is known as a "taper" charge or one in which the generator if connected to a discharged battery will deliver a high rate at the start of the charge, but as time progresses the rate will gradually fall until, at the end of the charge, it is down almost to zero.

This system usually includes a straight shunt-wound generator which builds up to a voltage equal to that necessary for the maximum charging rate at comparatively low speed and some form of vibrating voltage regulator whose function is to hold constant generator voltage. This is done by alternately cutting an external resistance in and out of the shunt field circuit. Its rate and period of vibration depend upon the speed at which generator is being driven and the battery current requirements.

TAPER CHARGING.

The voltage regulated or constant potential system of battery charging, which gives a tapering charge, Fig. 6, is based on the fact that the counter electromotive force or opposing voltage of a battery is lower when the battery is discharged than when it is charged. The difference will be in the order of 0.6 volts per cell, or for a 3-cell 6-volt battery will be 1.8 volts. Therefore, if the generator is set to hold 7.8 volts, equalling a fully charged battery, it will have, with a discharged battery having a counter electromotive force of only 6 volts, 1.8 volts available for forcing the charging current through the battery; consequently, the charging rate will be high. Leaving the regulator and generator characteristics out of consideration, the high current rate will be determined by Ohm's law, where E or voltage is the difference between generator voltage and battery counter electromotive force and R or resistance equals the sum of the battery and external circuit resistances. If $E = 1.8$ and $R = 0.06$, then the charging rate to the battery will be $1.8 \div 0.06 = 30$ amp. at the start. The rate will taper to zero when the charge is complete, at which point the battery counter electromotive force equals the generator voltage.

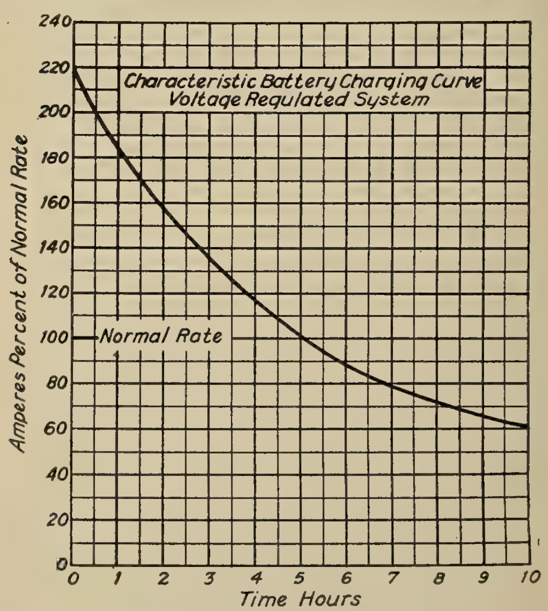
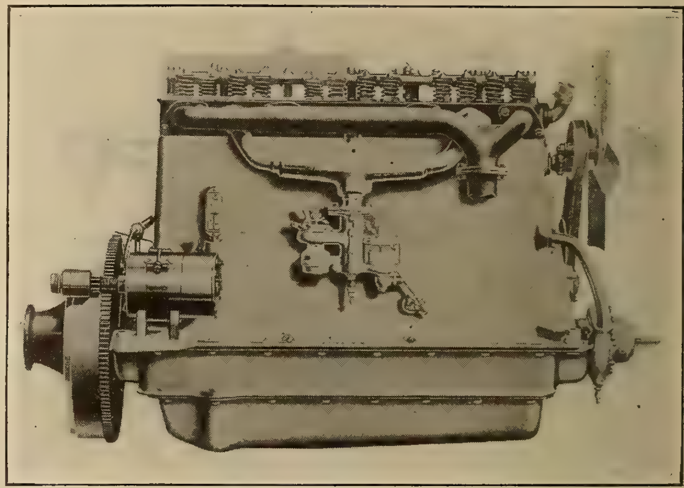


FIG. 6. CHARACTERISTIC BATTERY CHARGING CURVE, VOLTAGE REGULATED SYSTEM

In actual practice this condition is only approximated, that



INBOARD MESH STARTING MOTOR

is, the regulator or generator, or both, may be so designed that the inital rate will be lower than the rate indicated by the foregoing formulas, and the final rate will not be zero, but rather something of the order of 5 or 6 amp. This is done to prevent the generator from being excessively overloaded during the first part of the charge, and to make sure that the battery will receive a low rate overcharge after completion of the regular charge.

TERMINALS.

Car builders in many instances do not give the subject of connections and terminals the consideration that it should have. Terminals should be rugged to withstand vibration, and should so hold the cable that the effects of vibration at the point they are attached will also be minimized. Terminals should always be soldered to cables, but the solder should never extend beyond the last point of support of the cable; in fact, it is preferable that the terminal be so designed as to support the cable by means of a clamping band which encircles the insulation at a point beyond the bared portion to which the solder is applied. Above all, terminals should be tight on connection boards, as loose terminals mean extra resistance, and extra resistance in the lamp or ignition circuits means decreased brilliancy of lights or unreliable ignition. In the generator circuit of a third brush machine, extra resistance means increased generator voltage with attendant heating of the generator; and in the generator circuit of a

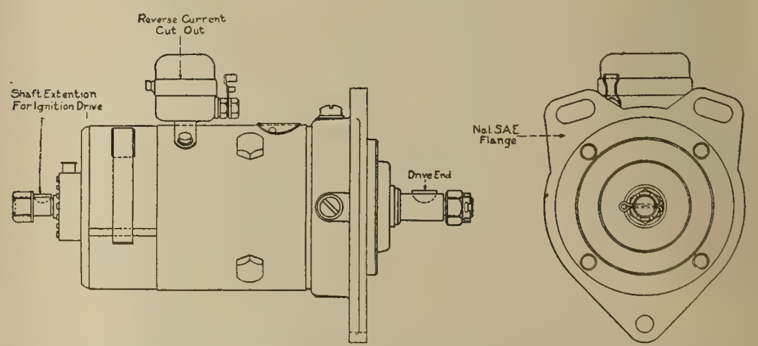
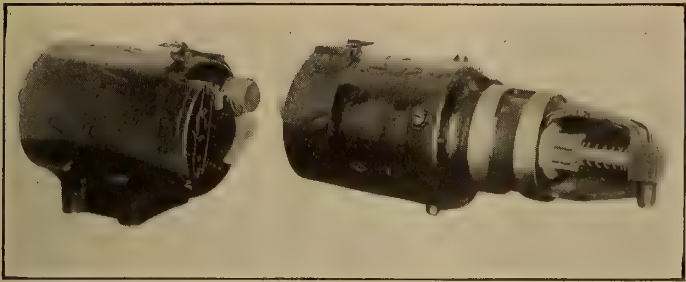


FIG. 7. DESIGN OF GENERATOR FOR FLANGE MOUNT (S. A. E. FLANGE DESIGN)

voltage regulated machine means decreased current output to the battery.

SOCIETY OF AUTOMOTIVE ENGINEERS.

The work of the Society of Automotive Engineers toward the standardization of all parts of the automobile has been of great value in simplifying and standardizing the mounting of electrical apparatus. The Society through the medium of its standards committees has recommended for adoption by manufacturers: three methods of mounting starting motors; two methods of mounting generators; one form of pinion and gear tooth.



GENERATOR FOR BRACKET MOUNT STARTING MOTOR FOR SLEEVE MOUNT (OUTBOARD SHIFT)

The three mounts are:

First: for inboard flange mount with three sizes of flange.
Second: for outboard flange mount with three flange sizes.
Third: for outboard sleeve mount. This is only one size.

In each of these, all dimensions which affect both motor and engine manufacturers are given. Roughly, these are: flange bolt drilling and location of holes; diameter of pilot; distance from flange face or dowel screw to flywheel teeth; and height of flywheel teeth above flywheel proper.

The gear and pinion tooth selected is of standard 8-10 pitch 20 deg. pressure angle.

The generator mounts are:

First: flange with two sizes to accommodate large or small machines.

Second: bracket with but one size laid out to accommodate the largest generator that may reasonably be encountered.

The flange method of mounting is employed when the generator is driven direct by a gear or sprocket running in the engine timing gear case. The engine half of the flange mount is then machined on the rear face of the gear case. The bracket mount is used where a separate shaft is brought out of the timing gear case for driving the water pump, ignition apparatus, or generator, or sometimes two or all three of them. In this case, the generator is mounted on the engine bracket and driven by means of a flexible coupling.

In these layouts, as in the motor layouts, all common dimensions are given, incuding shaft and sizes, coupling fits, and height of shaft above bracket, and in the case of the flange mount, shaft end sizes for gears or sprockets and drilling and shape of flange.

UNBALANCED FORCES IN RECIPROCATING ENGINES.

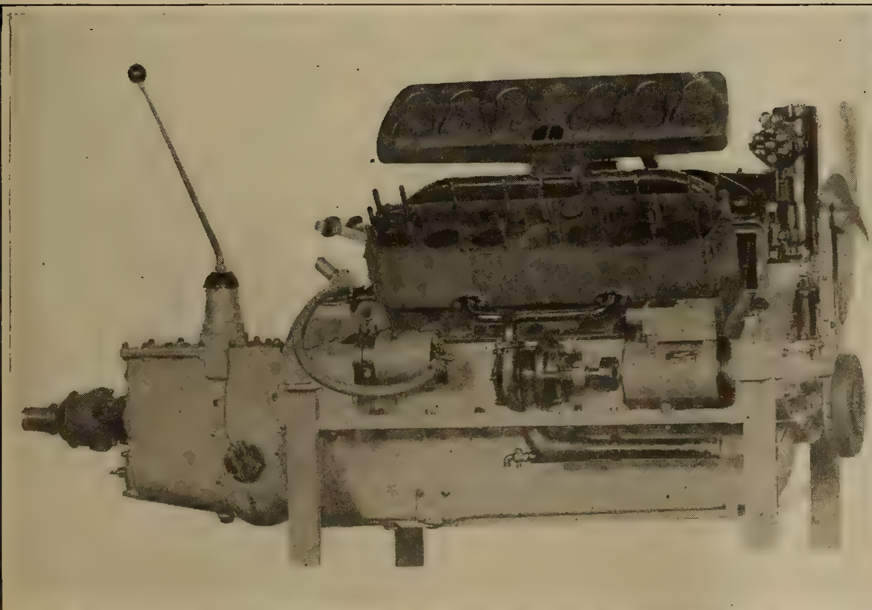
Writing in *The Automobile Engineer* for February, 1920, J. L. Napier treats with great detail the unbalanced forces at every 5° of the crank position of the engine, and takes into account all the various types and groupings of cylinders, from the 4-cyl. vertical engine to the "broad-arrow" type, with three groups of four cylinders.

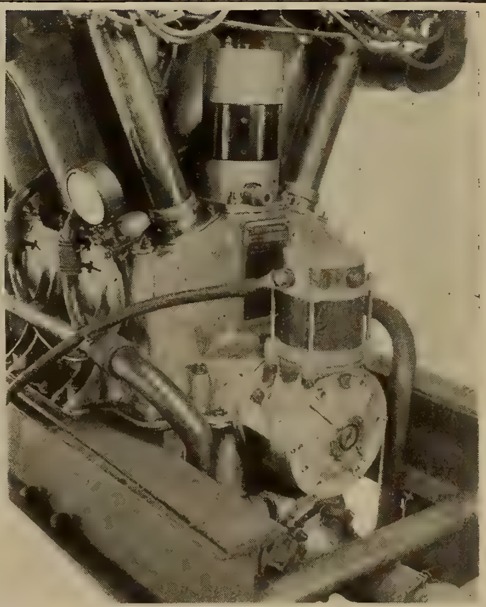
The author considers all unbalanced forces which tend to vibrate the engine as a whole to be transferred by stresses internal to the structure of a single plane at right angles to the center line of the crank-shaft.

The principal source of unbalanced tangential forces is the fluid pressure of the gas in the cylinders, and the principal source of unbalanced radial force is the inertia of the reciprocating masses. Interesting tables are given which allow curves to be plotted showing the piston acceleration, the unbalanced vertical force, and the torque due to inertia, with varying lengths of connecting rods. Concerning the "perfectly-balanced" six-cylinder engine, the author remarks that one is prone to ignore the effect of the tangential compound of inertia force in causing angular vibration of the engine about the crank-shaft center; the effect of inertia on torque is quite as considerable in the six-cylinder engine as in the four, but can be minimized by increasing the connecting rod length.—Abstracted by *The Technical Review.*

HIGH-SPEED RADIO-TELEGRAPHY.

In a test of high-speed radio transmission between Woolwich and Weymouth in which the messages were recorded in Morse code and in printed Roman characters, 2,017 words were sent in 30 minutes, 901 words in 8 minutes and 379 words in 4 minutes. The speed was limited only by the exigencies of mechanical design.—*Royal Engineer's Journal*, Feb., 1920.





STARTING MOTOR AND VOLTAGE REGULATING GENERATOR (LEFT). BIJUR AERONAUTICAL STARTER ON NON-DRIVING END OF ENGINE (RIGHT)

TRANSFERRING A BALE OF CANE FROM AN OX CART TO A RAILWAY CANE CAR, IN CUBA

Electrification of the Hershey Cuban Railway

A High Voltage Direct Current System

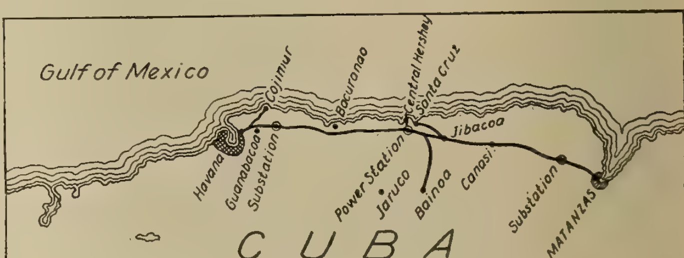
By F. W. Peters

At all large Cuban sugar mills, railroads for transporting cane extend in various directions to tap the areas where cane loading stations are located. Two-wheeled ox-drawn carts are used to gather cane in the fields and haul it to the loading station where it is placed aboard especially constructed cane cars which are later made up into trains and hauled to the mill. The necessity of grinding cane shortly after it is cut, in order to obtain a maximum sugar yield, renders desirable the maintenance of a reliable railway system to supply the mill with a continuous flow of cane, thereby eliminating "cane shortage" shut downs which prove so costly to the sugar operator.

The industry has assumed such proportions that the mills command attention not only for their size, intensive operation, and efficiency, but also for the supplementary industrial activities necessary to the support of the mills during that five-month period of 24-hours per day cane grinding when nothing but a break down or an important holiday is deemed sufficient cause to stop operations.

Hershey Central, a beautifully situated town overlooking the Gulf of Mexico, is located on the north coast of Cuba practically midway between the cities of Havana and Matanzas, some 56 miles apart. The major activity, at this as well as numerous other Centrals on the island, is the manufacture of sugar. This mill is now served by the Hershey Cuban Railway, a steam operated road having approximately 55 miles of single track. The present motive power consists of seven steam locomotives ranging from 20 to 40 tons on drivers. Both coal and oil fired types are in use, which on account of the very high cost of fuel in Cuba and the inefficient operation of such engines constitute an expensive item in overall operation and preclude an efficient expansion of traffic such as outlined herein.

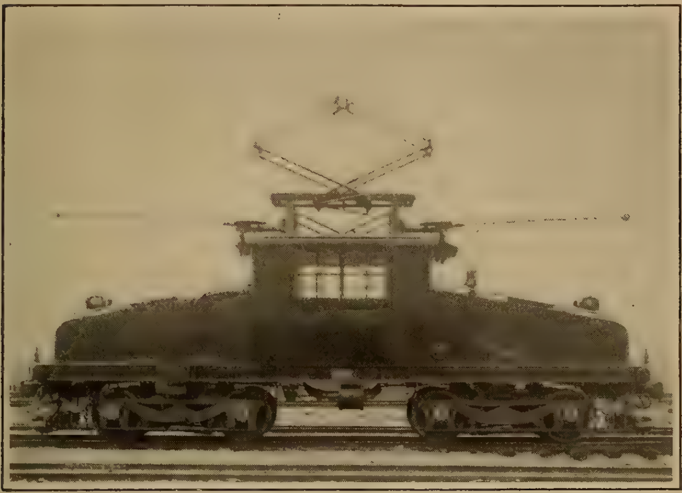
In keeping with the broad plans of the management, the road is being electrified, and extensions which will comprise the main line are being completed to Havana on the west, and to Matanzas on the east. Branch lines between Havana and Cojimar, 4½ miles, between the main line and Bainoa, 7½ miles, and between the main line and Santa Cruz, 4½ miles, are completed. These with numerous short spurs and



MAP SHOWING ROUTE OF THE HERSHEY CUBAN RAILWAY

sidings will total 80 miles of electrified single track. The road is built over a private right of way through a rolling country in which the ruling grade is 2½ per cent. The track is standard gage with 85 lb. per yard running rails, rock-ballasted over the greater portion.

The service to be maintained upon inauguration of electric operation will consist of cane and sugar transportation besides through and local commodity freight, express service, and multiple unit passenger train service operating on one-hour haedway between Havana and Matanzas.



A 60-TON, 1,200-VOLT DIRECT CURRENT LOCOMOTIVE

The 1200-volt direct-current electric railway system was selected by the railroad management after a thorough investigation of various types of electrified roads, as being that which would fulfill to the best advantage the present conditions of electrical operation as well as provide for efficient expansion incident to anticipated growth.

LOCOMOTIVES

The motive power furnished for operating the foregoing cane and general freight service consists of seven 60-ton four-motor 1200-volt direct-current electric locomotives arranged for multiple unit operation when necessary. The control provides for connecting the motors in series or series-parallel, and consists of two master controllers (one located at each driving position in the main cab) with resistors, dynamotor blower set, solenoid contractors, and other auxiliaries mounted principally under the end cabs. Power for operating the control equipment is obtained at 600 volts from the dynamotor. A pantograph type trolley is mounted on top of the main cab with provision for the convenient use of pole trolleys, to provide for operation over adjoining electric railways necessitating such type of trolley. Combined straight and automatic air brake equipment is used with two 35-cubic foot displacement per minute air compressors placed in the main cab and operated directly from the 1200-volt trolley wire.

MOTOR CAR EQUIPMENT.

The motor car equipment consists of ten straight passenger cars, three combination passenger and baggage cars, and two combination express and mail cars. The passenger cars seat 50 persons, having a free running speed of approximately 40 miles per hour, and will weigh completely equipped about 29 tons. Four motors per car are provided with automatic electro-pneumatic double-end multiple unit control equipment arranged to connect the motors in series and series parallel. Power for the control circuits and car lighting is obtained from a 32-volt constant potential generator driven by a 1200-volt direct-current motor operating from the trolley circuit. Pantograph type trolley and bases for pole trolleys are mounted on the car roof.

POWER GENERATING AND SUB-STATION EQUIPMENT

The power equipment selected to operate the railroad and to furnish commercial power to Matanzas and smaller towns along the right of way comprises a generating station, one main railway sub-station and two outlying automatic sub-stations. The generating station is equipped with three 2500-kva. turbine alternators and has four 600 hp. oil-fired steam boilers.

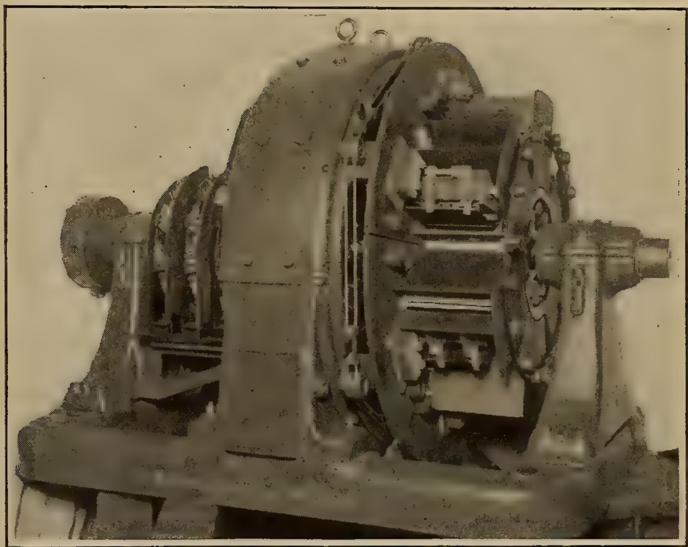
The main generating voltage is 2300 three-phase 60-cycle from which step-up transformers between the main 2300-volt bus and the high-tension bus distribute power at 33,000 volts three-phase to the outlying sub-stations and points of commercial distribution. Power for station auxiliaries and shops is obtained from transformers stepping down from 2300 to 480 volts. This latter voltage, largely used in sugar mill work, was selected to permit a direct tie-in when necessary with the main bus of the sugar mill power house which is close to, but distinct from the new railway station.

The railway synchronous converters located in the main station consist of two groups in parallel, each group comprising two 500-kw. 600-volt machines connected in series for 1200 volts. These receive their power from the main 2300-volt station bus through step-down transformers.

For oil firing a steam atomizing system is used with exhaust steam surface heaters arranged to heat the oil to the right viscosity for proper atomization. Two 7500-gallon capacity auxiliary fuel oil tanks are located near the boiler room, each of which holds approximately one day's supply based on the estimated load for the near future, while some distance away are the main oil storage tanks having a 500,000 gallon capacity. No attempt was made to utilize bagasse, the refuse from ground cane, as fuel for the railway power station since the quantity produced by the grinding rolls is practically all consumed by the sugar mill boilers.

Provision has been made for conveniently installing coal burning machinery without disturbing the boiler settings or auxiliaries should a readjustment in the relative price of coal and oil necessitate the use of coal for economy.

A spray pond constructed of concrete is located 600 feet distant from the power house and is connected by two 36-inch concrete pipes, one of which connects to the intake and the other to the discharge wells, in the generating room, used for the condenser circulating water. Three motor-driven 4600 g.p.m. high efficiency pumps which force the discharged circulating water through the spray nozzles are located in the pump house at the spray pond.



A 500-KW. 600-VOLT SYNCHRONOUS CONVERTER USED IN THE SUBSTATIONS—NOTE THE FLASH BARRIERS

SUB-STATIONS

The two outlying automatic sub-stations, one of which is located near Havana and the other near Matanzas, are duplicates and each contains one 1000-kw. group of synchronous converters consisting of two 500-kw. 600-volt machines con-

nected in series. A third 500-kw. 600-volt spare converter is provided with change-over switches so that it may be conveniently substituted for either the high or low machine of the group. Three 350-kva. single-phase 33,000-volt high-tension self-cooled transformers having double secondary windings are regularly employed for operating the converters with a fourth transformer supplied as a spare. The switching equipment is completely automatic in operation and is similar to those which during the past few years have proven very successful in many parts of the United States. No regular attendants are required for the operation of the equipment since it starts automatically on a power demand and stops when the demand ceases. During operation the equipment is protected from injury due to excessive overload by the use of flash barriers and load limiting resistors on the direct-current side of the machine. All irregularities emanating from disturbance on the high-tension lines or improper functioning of the equipment is fully protected against so as to promote reliable operation. Two feeder circuits leave each sub-station to allow the trolley and line feeder cable to be sfectionalized in front of each station.—Abstracted from *General Electric Review*, April, 1920, pp. 307 to 312.

Future Developments of the Rigid Airship*

Methods of Utilizing Excess Hydrogen

By Squadron Leader P. Litherland Teed, R.A.F.

NOW that the dawn of the English Commercial Airship era is breaking, it is appropriate to point out that there are fields of technical development which commercial enterprise must investigate to secure reductions in the cost of airship operation.

The first subject for investigation is hydrogen economy.

When an airship flies it decreases in weight by the amount of gasoline and oil consumed, or, in other words (if the secondary effects of superheating and super-cooling of the hydrogen are for the moment neglected), it can be said that the airship increases in buoyancy or lift to an extent which is a function of its *horsepower hours* of flight.

The airship engine may be taken to consume 0.53 lb. of petrol and oil per horsepower hour, consequently taking as an example an airship of the German L-30-39 class, these ships which are of 1,300 horsepower will increase in buoyancy by:

$0.53 \times 1{,}300 = 689$ lbs. per hr. of full power flight.

To prevent the airship's rising from this continually increasing buoyancy during flight is simple; in the early stages of flight the tendency to rise can be counteracted by the elevators, but with lapse of time the ship becomes so light that this ceases to be an effective remedy and it is then necessary to decrease the lightness of the ship by releasing hydrogen. Now since, for reasons of controllability, it is necessary when landing an airship at the end of a flight that the airship should be in equilibrium (i.e., equal in weight to the weight of air displaced), it is ultimately necessary to valve hydrogen equal in lifting power to the weight of the gasoline and oil consumed during the flight.

To put this statement into definite terms is simple. On an average, 1,000 cubic ft. of hydrogen has a lift or buoyancy of 65 lb., consequently

0.53 lb. will be lifted by $\frac{1{,}000 \times .53}{65} = 8.2$ cu. ft. of hydrogen.

Thus there is a hydrogen consumption from this cause of 8.2 cu. ft. per hp-hr. of flight, or applying this to the L30-39 class of Zeppelin, this type of ship will be ultimately forced to release hydrogen equal to:

$1{,}300 \times 8.2 = 10{,}660$ cu. ft. per full power hour of flight.

To express this waste of gas in money in these days of fluctuating prices and rapidly improving efficiency in the technology of hydrogen production is difficult, but it is non-controversial to say that the total cost of hydrogen in England, including labor, insurance, depreciation, material, etc., is at present approximately 15 shillings per 1,000 cu. ft., consequently the airship taken as an example will consume: $10.7 \times .75 = £8$ worth of hydrogen per hr. of full-speed flight, which is a serious charge, but one ultimately preventable provided sufficient inducement is given to engineers to deal thoroughly with the problem.

There are at least three methods whereby increase in buoyancy, with its present attendant unnecessary hydrogen loss, can be dealt with.

(1) Water recovery from the engine exhaust.

(2) Picking up water from the sea.

(3) Burning hydrogen (a) to produce water, (b) to produce power.

WATER RECOVERY FROM THE ENGINE EXHAUST.

Gasoline, which is a mixture of various hydrocarbons may be taken, for the purpose of this note, as being represented by the formula, C_7H_{16}, therefore the complete combustion of a mixture of gasoline vapor and air in the cylinders of an airship engine can be expressed as follows:

Gasoline	Air		Carbon dioxide	+ Water	+ Nitrogen
C_7H_{16}	$+\ 11(O_2 4N_2)$	=	$7CO_2$	$+\ 8H_2O$	$44N_2$

But the molecular weight of gasoline is 100 and that of water 18, therefore it can be deduced from the above equation that: 100 lb. of gasoline produce on combustion $(8 \times 18) = 144$ lb. of water.

Thus the weight of water passing as steam out of the exhaust pipe of a gasoline engine is nearly one and a half times the weight of the gasoline entering the carburetor, so, if effective means were evolved of condensing this steam by cooling the exhaust gases below the boiling point of water, it would be possible to maintain an airship in a state of approximate equilibrium during flight *without the loss of hydrogen.*

At first sight it might be said that the above is the solution of the problem of hydrogen economy during flight, but, though it may be, it is at present not much more than the outline of a procedure which by careful attention to detail may be developed in a practical process for commercial airships.

Among the difficulties of this procedure may be mentioned the quantity of heat to be absorbed; the exhaust gas of a gasoline motor contains about the same quantity of heat as is normally dissipated by the radiator of the engine, consequently, the cooling of the exhaust by this means would increase the head resistance of the ship and would also be subject to objection on the grounds of additional weight.

Another difficulty is the actual catching of the water; after the exhaust has been cooled below the boiling point of water (if the vapor present is neglected), the volume of the water particles is about 0.01 per cent of the volume of the exhaust gas, therefore, to prevent these water particles from being carried out of the exhaust pipes, the particles in the exhaust gas require considerable surface to which they may become attached.

While it is not difficult to recover water from the exhaust of internal-combustion engines—it has been done several times in the case of Diesel engines, running in the desert to make up cooling water losses—it is difficult to do so in airships without somewhat heavy apparatus, which, besides the objec-

*From *Aeronautical Engineering* (supplement to *The Aeroplane*), March 31 1920, pp. 677-8.

tion of weight, has the additional disadvantage of increased head resistance, but attention to design will reduce both these objections considerably, and it may well be that hydrogen consumption from increase in buoyancy may be reduced by the method outlined above.

PICKING UP WATER FROM THE SEA.

Since the commercial utility of rigid airships lies chiefly in long-distance trans-oceanic flight, increase in buoyancy might be dealt with by picking up sea water from time to time equal in weight to the gasoline and oil consumed.

A method whereby this can be achieved consists in forcing the airship under power to within 400 ft. of the surface of the water and then dropping a streamline vessel like a paravane, which is connected to the airship by a fabric hose; the streamline body with the necessary stabilizing surfaces is fitted with a water propeller at its stern, which, by being towed through the water, drives a reciprocating pump within the paravane delivering via the fabric hose into the ship.

This device can be made within a reasonable weight to deliver a ton of water in five minutes with a satisfactory mechanical efficiency, but its employment in the future seems problematical, as at present it has not the approval of pilots for two main reasons, one of which is the intermittent operation of the device combined with the necessity for very careful control of the ship during its operation, and the other is that in fog when the surface of the water cannot be seen, the risks of attempting to fly at this low altitude are too great to allow of using the apparatus.

BURNING HYDROGEN TO PRODUCE WATER.

To burn hydrogen to save hydrogen seems at first paradoxical, if not absurd; but an examination of the facts will show that the procedure has certain points in its favor. Water contains one-ninth of its weight of hydrogen, or, in other words, one part by weight of hydrogen on burning in air makes nine parts of water. Confining the examples for the development of the argument to approximations, if under the econditions prevailing 1,000 cu. ft. of hydrogen weighs 5 lb., then, on burning this volume of gas in air, 45 lb. of water will be produced, which, it is assumed, at this stage, will be satisfactorily condensed in the ship.

Now, under average conditions, 1,000 cu. ft. hydrogen would give a lift or buoyancy of 65 lb., therefore, by burning 1,000 cu. ft. of hydrogen, and condensing the resulting steam, the airship would decrease in lift by

$$65 + 45 = 110 \text{ lb.}$$

so it is seen that instead of having to valve 8.2 cu. ft. of hydrogen per hp-hr. of flight, by burning hydrogen and collecting the water only

$$\frac{1{,}000 \times .53}{110} = 4.8 \text{ cu. ft.}$$

would be lost per hp-hr. of flight in order to keep the airship in equilibrium. Thus the paradox "to burn hydrogen is to save hydrogen" is established.

An advantage claimed for this method is that the effective recovery of the water would be easier as the percentage of water in the products of combustion would be greater than in the exhaust of the gasoline engine; after these products have been cooled to below the boiling point of water (if the presence of water-vapor is neglected) they would contain 29 per cent of water by volume instead of the 0.01 per cent contained in the exhaust of the gasoline engine under similar conditions.

It is probable that the process just outlined could be more rapidly applied with success to airships than the first method which was described. However, this last process has only the potentiality of reducing the present waste of hydrogen but not of stopping it.

BURNING HYDROGEN WITH THE PRODUCTION OF POWER.

The burning of hydrogen to save hydrogen is a wasteful process (though it would do much to stop the present more wasteful procedure), for weight for weight hydrogen has three times the calorific power of gasoline, so that 1,000 cu. ft. of hydrogen, since it weighs about 5 lb., is equal in calorific value to 15 lb. or 2 gal. of gasoline. Therefore, if hydrogen equal in buoyancy to the weight of gasoline consumed were burnt in an engine, the airship besides remaining in continuous equilibrium (except for secondary effects) would have a greater speed for the same gasoline consumption, or an equal speed for a smaller gasoline consumption.

It has already been shown that 8.2 cu. ft. of hydrogen has a lifting power equal to the weight of gasoline and oil consumed per hp-hr.; now assume that this 8.2 cu. ft. of hydrogen is burnt in a special internal combustion engine of the same efficiency as the present gasoline engine, the power developed will be:

$$\frac{8.2 \times 5 \times 3}{1{,}000 \times 5} = .25 \text{ hp.}$$

That is to say, if an airship is constructed to develop 80 per cent of its power by gasoline engines and 20 per cent by means of a hydrogen engine the ship will (except for secondary effects) remain in constant equilibrium during the whole period of its flight, or, in other words, the maximum endurance of an airship so fitted with a hydrogen engine would be 25 per cent greater than that of a ship similar, except for the whole power being developed by gasoline engines.

Examining the economics of this scheme, if gasoline costs 2s. 6d. per gal, and hydrogen 15s. per 1,000 cu. ft., the cost of power produced by hydrogen is over two and a half times more expensive than when produced by gasoline (assuming equal thermal efficiency in the gasoline and hydrogen engines). However, since in the present method of operating airships this hydrogen is entirely wasted, and in the suggested method it increases the maximum endurance of the ship by 25 per cent, it must not be rejected on economic grounds.

Examining the technology of this scheme, since the velocity of explosion of hydrogen and air mixtures is enormous (when compared to gasoline and air mixtures), it is probable that the moving parts of a hydrogen engine would have to be more massive than those of a gasoline engine of the same power, that is to say, a hydrogen engine would be a heavy engine on the basis of weight per hp. Confirmatory of this, it may be mentioned that in his recent lecture to the British Association on Airships, Wing Commander T. R. Cave-Brown-Cave stated that, using an ordinary airship engine with hydrogen as the fuel, the maximum power output was 25-30 per cent of that obtained from the engine running on gasoline; attempts to obtain large power output produced serious cylinder detonations.

Owing to the difficulties (not necessarily unsurmountable) of making a light hydrogen engine, V. Bellamy has invented an ingenious device whereby a very weak gasoline and air mixture is re-enforced with hydrogen to such an extent as to give gasoline economy and, at the same time, full power output from the engine. Since this device has all the advantages obtainable from using hydrogen as a fuel, it is probable that in the future it will be considerably employed. Though it does not effect hydrogen economy it may be said that, because it allows a higher commercial load to be carried by an airship (owing to reduced gasoline consumption), it has potentiality of doing rather more, as it increases the maximum revenue obtainable from freights, and reduces the actual fuel cost of transporting that freight.

ULTRA-VIOLET LIGHT TEST FOR BALLOON FABRICS.

THE deterioration of balloon fabrics is supposed to be due to the action of heat, light and moisture. It is believed that ultra-violet in sunlight is one of the chief factors and in order to obtain an accelerated aging test the experiment was recently tried of exposing fabrics to a mercury vapor arc. The tests were not conclusive.

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SOARING OVER THE CRATER OF MOUNT LASSEN, CALIFORNIA

A Pack Train of Eagles*

Suggested Use of Aircraft in Mining Operations Where Roads and Trails Are Absent

By Eugene Shade Bisbee

A CERTAIN mining company had received several reports from different engineers about a property in a remote part of Idaho. Practically all of the reports were in favor of the property, which the company seriously considered buying. As a final precaution the president sent a young mining engineer to report. After a month or more, this telegram was received: "Vein all right; sample correct; ore is there. To get the stuff out would take a pack train of eagles." This story was told a long time ago, and the acumen of the young engineer was admired, his reference to a "pack train of eagles" exciting a hearty laugh wherever the story was told. Times have changed. What then appeared an absurdity has now passed beyond the air-castle stage. A "pack train of eagles" may not elicit much surprise in the mining industry in the course of a few years. In this day of keen competition the man who says "It can't be done" wakens some morning to discover that somebody has done it.

I have shown before the value of the airplane in preliminary mining operations, the saving of time and money and the greater accuracy of the work. Since that article appeared several American airplanes have been put to work in Peru; and down in Mexico an American mining operator has petitioned the Carranza government for permission to use an airplane in his work. Therefore, it has been demonstrated that aircraft possess a unique usefulness in this field. They not only can be used to survey and map the significant area, but also to carry men in and out and to transport supplies, material, and high-grade ore. They are destined to play a part in mining development, but they will co-ordinate with the prosaic mule in transportation and never wholly replace him in certain fields that are all his own. In fact, if a mine needs the services of an extra mule it will be the airplane that will carry the mule in, transporting the animal fifty times as fast as his own sure feet would take him there and taking his feed along to boot. For the airplanes that are going to be used in mining will be built to carry not less than 1,200 lb. of useful load.

For this new work both the airplane and the dirigible will be used, as the lighter-than-air craft needs less landing space than the plane, and will, generally, be called upon to transport the more bulky freight, leaving the lighter packages, the high-grade ores and bullion for the speedier plane. In carrying vanadium, uranium and radium ores at present from Paradox Valley to Placerville, in Colorado, four-horse teams are used, and from two to four days are required for the trip of about seventy miles. An airplane would take 1,000 lb. of the ore, winter or summer alike, over the mountains, in less than an hour, making not less than half a dozen trips a day and keeping it up, regardless of ground conditions of snow, ice, land-slides, or anything else, as continuously as may be necessary. Returning to the mine from the railroad shipping point, the airplane can take in men and emergency supplies; it will take the superintendent or other officials back and forth on business; it will keep the operators in continuous touch with both ends, thus making for higher efficiency and greater production and rapid delivery of the product to the base of final disposition.

Very rich ores may be transported in small compass, but an airplane will carry in four days—the time required by a horse or mule team to go one way—not less than twelve times the weight or ore brought out by the animals during

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a like period of time. And it must not be overlooked that it will make twelve return trips, taking in all kinds of necessary supplies or men.

Although it has been said that the airplane will never entirely supersede the mule or the horse in the field where those animals have been pioneers, certain comparisons between draught and pack animals and the airplane throw an interesting light by contrast. After the location has been made by airplane exploration, and the mosaic maps have been prepared and the ore uncovered, tools, men, and supplies must be sent in. The lighter of these tools and supplies can be transported by plane, the heavier by team. Consider the saving of time by the assurance that every bit of smaller machinery, every tool, all supplies, and every man, will be on the ground and ready for action by the time the heavy material has arrived by mules, because they have been taken in by plane, at a speed more than twenty times that of the animals that plod over the rough ground, while the plane darts to and fro above them; the whole circumambient blue being its magnificent roadway. Dwell for a moment upon the toiling string of llamas that pursue their course down the slopes of the Andes, their backs laden with precious ore. All day long they trudge onward, urged by their drivers, who, by the way, are ever careful not to get within "spit-shot" of an irate llama. For there are at least two things that start a fight in South America; one is a llama that believes itself to have been abused, the other is a man whom the llama believes has abused him and into whose eye, from a distance of fifteen or twenty feet, the llama has violently spit. The insult is eradicable only by the near-death of the llama, which can only be saved by the interposition of someone in authority.

While the llamas are covering the distance from the mine to the railroad or seaport the airplane is ever speeding above, back and forth, with mineral and supplies, and even men, doing every day the combined work of not less than thirty llamas, and neither complaining of treatment nor spitting in one's eye!

Statistical details may be made less uninteresting by showing that a pack train of sixty mules can carry approximately, 24,000 lb. some twenty-odd miles over mountain roads in a day of eight hours. Six men will be required to drive sixty mules, and six men will draw, again approximately, $36 per day in wages. Add to this the cost of the rations for the men and the animals. For the last named the cost will be, based upon the present price of oats and hay at Atlantic tidewater, $1.06 per day, as a healthy, hard-working mule will need sixteen quarts of oats and twenty pounds of hay daily, if you expect the animal to work. The men will eat up more money, if not an equivalent weight in food.

While the mule train is making its twenty-odd miles per day, with 24,000 lb. of useful load, the airplane is hurrying to and fro at eighty miles an hour, as against the three miles of the mules, and taking with it on each trip about 1,200 lb., or at the rate of a round trip from the mine to the railroad and back, the distance being assumed to be twenty miles, in half an hour, not allowing for time to load and unload. During a day, therefore, the plane could carry back and forth over such a line sixteen loads of 1,200 lb. each, or something better than half of what sixty mules could transport. At the end of the second day the plane would have equaled the work of the sixty mules for the first day, and from then on there would be no contest—just a runaway for the plane.

Considering the cost of the two factors in this work, the mules and their drivers would consume more than one hundred dollars per day in food and wages; the plane would eat up 160 gallons of gasoline and the pilot would cost $10 each day. Depreciation of both airplane and mules is not considered, but both depreciate proportionately in value as carriers.

The Andes in South America offer a suitable field for the use of aircraft. There are not many roads and there are few trails. Both prospecting and development could be served in almost inaccessible situations. Tools and food supplies could be brought in at a saving in time and with a sureness that could not be equaled by any other means. Bolivia, Peru and Brazil embrace considerable areas of promising mineral ground, it may be conjectured, but much of it is inaccessible on account of absence of roads and trails. The Chilean nitrate fields could have been reached by exploring parties in no better way than by airplane.

The west coast of Mexico, the Sierra Madra country, and other parts of Mexico, indifferently served by roads, present an inviting field to the prospector-aviator.

The Arctic regions, Canada and northwestern Canada, Siberia, China, and Africa are countries in which ordinary means of transportation and travel are indifferent or almost wholly inadequate. The desert regions of Australia form a vast area presenting possibilities for exploration by flying machines.

As an example of the excessive time consumed in certain features of mine-examination work, mention may be made of a copper region east of the Mackenzie River, in northwestern Canada. It possesses many of the characteristics of the Michigan copper country. To visit this region and complete an examination would require two years, one year to go in and another to come out. With an airplane it is probable that the trip could be made from Dawson in a day's time.

There are certain inherent limitations on the use of airplanes and dirigibles. Both are dependent upon a gasoline supply. In the case of using such appliances in prospecting, the conditions are much the same as would apply to an ocean steamer with but a single base for its fuel supply. The maximum outward trip mileage is equal to but 40 per cent of the fuel supply. This leaves only a 10 per cent margin on both the outward and return voyages. Further, it would indicate that, if the gasoline supply in the case of an airplane would be sufficient for 500 miles at economical speed, and with a normal load of freight and passengers, the extreme safe radius of action would be 200 miles. Thus, from a given center of gasoline supply, the area included within a circle of 400 miles diameter could be served. With a mileage supply of gasoline equal to 1,000 miles, the radius would be 400 miles, and the area, a circle of 800 miles' diameter.

By establishing a supplementary supply point and dividing the trips into pairs, one for extra gasoline transport to the supply point and the other for freight service, the trip in any one direction could be doubled. This computation is based on the assumption that the weight of gasoline carried as freight would be equivalent to the 500 or 1,000 miles assumed respectively for such case. These figures assure to a considerable extent that territory within a practicable distance could be served, although special arrangements would be necessitated for trips from 500 to 1,000 miles in length. These would, of course, require gasoline-supply points at suitable landing places en route. The handicap would be the necessity of bringing gasoline to the supply points. By employing two machines, one could be used for supply stations with gasoline and the other for freight and passenger service.

With the use of airplanes, the practical difficulty would be to find suitable landing places. Necessarily, the first trip would be the most hazardous, but after marking and mapping the landing points, the continuation of service would not be supremely difficult. It is worthy of note that in regions containing a number of lakes, as is the case in many parts of Canada, the hydroplane would be especially adapted for utilizing the lakes for landing places.

In the case of the "blimp" or dirigible, the radius of action would be greater and would admit of reasonably close calculation. There would be a nice division between fuel weight and freight weight. Once a definite route had been established, the proportions of freight and gasoline would be constant. As in the case of airplanes, longer voyages could be attempted by establishing supply stations. As the dirigible could land in a limited area, the pioneering trip of the dirigible would be less hazardous than that of the airplane.

The weak point of the dirigible is the difficulty of adequately protecting it at terminals. Some kind of a structure would be required, at least at the starting terminal, and, where established service ensues, also at the distant terminal. Unlike the airplane, the dirigible could travel at night. The expense of a terminal shed would be almost prohibitive.

Probably the most vital question would be the one of safety, and, after that, the cost. The construction of both airplanes and dirigibles has advanced to the point where both types are safe structurally and mechanically for normal conditions. The danger lies in operation and abnormal weather conditions. Experienced operators could undoubtedly be obtained, and by confining actual flying to periods when weather conditions are suitable the risk could be minimized. Transportation through the air would probably never be as safe as ordinary travel. Hidden defects in mechanical equipment might easily force landing in unsuitable and dangerous places; particularly so where it is proposed to use such devices over mountainous country, as would most certainly be required in prospecting. A highly specialized class of skilled labor would have to be employed, and, for service over a long period, an organization with headquarters and repair shops would be necessary.

The cost of operation, as previously indicated, would be high, but in the aggregate it is doubtful if it would exceed the cost of trails or roads. A 100-mile trail at $500 per mile would equal $50,000; a wagon road of the same length at $2,000 per mile would be $200,000. Road and trail cost would of necessity be comparatively figured in any actual case. Considering the saving in time, as pointed out before, the number of cases where flying machines could be used for prospecting and development would not be negligibly small.

Already the airplane is a common sight in the oil fields of the West, and the skies of California are never clear of its gauzy wings. It has conquered the Atlantic and is about to venture the Pacific for a $50,000 prize. Airplanes are no dream; they are one of the hardest of hard facts; they are the carriers, the fleet messengers, the fighting wasps and the unconquerable servants of man, who has created and harnessed them. Soon they will swarm in every sky, and the mining man who has not adopted them for his purpose will compare with the farmer who, on his way to market with his horse-drawn produce, is passed by the other chap in the motor truck, on his way home with the cash in his pocket.

RECENT PROGRESS IN THE INVESTIGATION OF THE UPPER LAYERS OF THE ATMOSPHERE.*

By DR. K. SCHOLICH.

EVEN at the very beginning of systematic observations of meteorological phenomena, early in the previous century, the significance of the occurrences in the upper layers of the atmosphere was recognized. However, meteorologists were long obliged to confine their observation merely to the trend followed by the clouds. It was not until the turn of the century at the beginning of our modern conquest of the air, when the necessity for information concerning the atmosphere became indispensable, that methodical investigation of the upper atmosphere was instituted.

Pilot balloons have been of especial service in this respect, whether sent up empty for the purpose of the rapid measurement of high winds or whether provided with registering apparatus so as to furnish data with regard to air pressure, temperature, and humidity of the upper regions of the atmosphere. These rubber pilot balloons possess the great advantage of making their entire upward journey with a constant vertical velocity, as was proved by Hergesell. The information obtained from pilot balloons with regard to atmospheric phenomena has been enlarged particularly in Germany by means of kite ascensions.

During the late war both sides experienced the necessity of placing the military weather service upon as broad a basis as possible. It was particularly necessary to provide the air service with exact data concerning the air currents in the middle layers of the atmosphere. Because of the blockade Germany found herself short of rubber for the making of pilot balloons and, therefore, employed as a substitute paper made air tight to a certain degree by means of suitable impregnation. These balloons naturally did not possess the unlimited ascensional power of the rubber ones, but since they were able to attain an altitude of about 6,000 meters they were sufficiently servicable for the needs of the air service, and because of their greater cheapness they will doubtless be employed for practical weather service even during times of peace.

The rapidity of ascent of the paper balloons is, however, not the same at all heights as it is in the case of the rubber balloons; consequently their course must first be determined by empirical methods. Afterwards it is sufficient to observe the ascent of the balloons from a given point.

A very great disadvantage was experienced in the determination of wind conditions under a cloudy or rainy sky, and this was a serious matter, particularly for the artillery. The French were the first to obviate this difficulty by the ingenious method of sending up a pilot balloon provided with a number of melinite cartridges arranged in a row along a fuse in such a manner as to explode at given intervals during the ascent. The resulting detonations were received in sound meters and these acoustic signals were evaluated by means of simple graphic methods similar to those employed for optical signals during fine weather. In this manner it was usually possible to make measurements of the velocity of air currents up to an altitude of 7,000 meters. The kite measurements previously made as a usual thing attained only very moderate heights.

Because of the discontinuation of meteorological information over the domain of the Atlantic Ocean, the prediction of storms was made considerably more difficult for the Central Powers. On this account it was more necessary than it was previously to obtain and make use of information concerning the distribution of temperatures, humidities, or air pressures in the upper layers of the atmosphere. Since, however, kite stations require not only an extensive provision of apparatus but even more a skilled staff, and the latter cannot be quickly trained, difficulty was experienced in rapidly increasing such stations. On this account recourse was had to flying apparatus as a substitute for kites. These were furnished like the kites with registering apparatus and succeeded in securing the desired data. Furthermore, the art of photogrammetry, which made excellent progress during the war, was impressed into service of the weather bureau. It is quite possible by taking records of two points at a certain distance from each other, to determine the height and also (an especially important point) the angle of inclination of cloud strata. This method is especially valuable for the investigation of the otherwise almost inaccessible stratum of the lofty cirrus clouds, and it is precisely in this stratum that the processes of circulation are of supreme significance as regards the origin of storms upon the surface of the earth.

*Translated for the *Scientific American Monthly* from *Umschau* (Frankfurt-on-Main).

NEW USE FOR ABANDONED MINES.

EVEN old abandoned mines are going to be put to some possible use according to the latest suggestion: A mine superintendent in the Joplin-Miami, Mo., district has visions of making a fortune out of mushroom raising in the abandoned mine drifts in that section. They are continually warm, just about moist enough, and in those where mules have been utilized for ore hauling there is plenty of good soil. The superintendent has rigged up an ingenious electric lighting scheme, with tinted globes, some one having told him mushrooms must have a little light, even if it is not sunshine, and he has planted his first bed and is awaiting results. If it works he estimates there is enough acreage in the abandoned mines in the district to produce mushrooms for the whole world.

Airplanes in Mine Rescue Work

Quick Transportation of Rescue Apparatus to Mine Disasters

By F. J. Bailey

Assistant to the Director, U. S. Bureau of Mines

In the fall of 1919, the U. S. Bureau of Mines began an inquiry as to the possibility of utilizing airplanes in conjunction with its rescue work, for quickly transporting engineers and oxygen rescue-apparatus to mine disasters.

It was realized that this proposed use of airplane has serious limitations, and, if it were feasible, that the Bureau would have to rely on the coöperation of the established aviation fields of the U. S. Air Service for furnishing airplane service. Therefore, Van. H. Manning, Director of the Bureau of Mines, under date of October 28, 1919, wrote the Director of Air Service outlining the rescue and first aid organization of the Bureau, the location of headquarters of district engineers, the distribution of safety cars and stations, and other essential details, and asking whether the Air Service could coöperate with the Bureau in the event of serious mine disasters. Major-General Charles T. Menoher, Director of Air Service, responded that the Air Service would be glad to coöperate insofar as possible, and designated those Air Service stations nearest the district engineers' headquarters, which might be best able to assist.

The Bureau of Mines has ten mine rescue cars and eight mine safety stations distributed throughout the mining regions of the United States. The cars are each equipped with sets of oxygen mine-rescue breathing-apparatus and first-aid supplies. The car personnel consists of a mining engineer, surgeon, foreman, first-aid miner, clerk and cook. A foreman miner is in charge of each station and at five of the eight stations are mine safety trucks. The work of the cars and stations is twofold: (1) Assisting in rescue and recovery work at mine disasters, and (2) training miners in mine rescue and first-aid methods, and in investigations looking to prevention of mine accidents. The country is divided into nine safety districts, with nine district engineers in charge.

A preliminary survey has indicated that airplane service might be effectively utilized in the flat-flying coal-fields of Illinois and Indiana, and a coöperative agreement has been made whereby McCook Field, Dayton, Ohio, will maintain in readiness planes for assisting the Bureau of Mines safety station at Vincennes, Indiana, in its rescue work.

The Bureau of Mines district engineer at Vincennes will collect data on possible landing-fields near the mines in this district, with maps indicating these land-places, their proximity to mines, or to towns and railway stations.

In event of the Vincennes station receiving word of a serious mine disaster at a mine where a landing field is available near by, or where train or auto connection could be made with a decided saving of time, a call for planes could be sent to McCook Field. The planes could land at the Vincennes municipal landing field, where the district engineer or foreman miner of the Bureau's station would be waiting, taking on gasoline and other supplies needed from the Bureau of Mines service station, maintained there, and carry the Bureau's engineer with sets of rescue apparatus to the landing field near the scene of the disaster.

The Bureau's engineer will thus be able to assist in directing the preliminary steps in effecting an organization for recovery work. In the meantime, a fully equipped Bureau of Mines rescue car or auto truck can be rushed to the mine, and on arriving there will find an adequately directed organization already functioning, thus saving valuable time. This may result in saving lives that might otherwise be lost.

Considerations as to Effectiveness of Airplane Use.

Much remains to be done before any decisive statements can be made as to the extent and effectiveness with which airplanes can be utilized generally in mine rescue work throughout the country. The difficulties and problems involved are many, some of these are discussed in the following paragraphs:

The distance of the Air Service stations from the Safety stations, and then to the mines, is a prime consideration. The Air Service stations are on an average of 150 miles from the safety stations, but some of them are much farther. Information as to flying time compared with time of travel by railroad or auto service is needed to predict whether airplane service, or combined air and surface service could be utilized with advantage.

The greatest problem is that of suitable landing fields. First, fields must be available at the town where the safety headquarters are situated; second, fields must be established at the mines. As regards establishing landing fields near mines, careful survey for level places that could be prepared without much difficulty is necessary. In mountainous mining districts there are at many mines no level places suitable for landing. Such conditions are found in metal and coal mining districts of the Rocky Mountain States and the Pacific Coast States, and in a number of the coal fields of the Appalachian region.

The present types of airplane require a landing space about 1,800 feet in extent in both directions. The development of planes capable of ascending from, and descending to, a landing within a limited area would overcome the present lack, at many mine, of safe landing areas.

Carrying Capacity and Flying Radius.

The service stations must have planes suitable for the work. Some Air Service fields are not at present equipped with types of planes suitable for carrying additional load, such as a passenger and rescue apparatus, or with planes carrying sufficient gasoline to provide a good flying radius.

Flying at night, especially in a mountainous country, would not be feasible. Neither could ships safely take the air in stormy weather. In regions of heavy snow, as in the Lake Superior District, planes could not be used in winter months, because the obliteration of land-marks by a deep blanket of snow makes it difficult for the aviator to pick his route with certainty.

An aerial map of the mining districts, showing safe landing fields, established aerial routes, and similar data is essential. The Civil Operations branch of the Air Service has made much progress on the mapping of commercial landing fields, and the development of a system of aerial routes. The Bureau of Mines engineers in their field work will be able to compile data on the surface conditions near each mine visited, and map places suitable for landing fields.

Conclusion.

In conclusion it should be remarked that too much should not be expected for the present in the use of airplanes in mine-rescue work. The prospects for such utilization in the mountainous districts of the West, or in hilly regions of the East, are not bright. In the mining regions of Illinois, Indiana and other middle states where the surface is comparatively level, there are excellent prospects that airplanes can frequently be used with advantage. If such use should result in the saving of lives at even one disaster, it would amply justify all the time and effort expended in this work. Moreover, as the commercial use of the airplane expands and improved types capable of landing in a small area appear, the field of application of airplanes to mine rescue work will be greatly broadened.—U. S. Bureau of Mines, Reports of Investigations.

Automobile Exhaust Gases in Vehicular Tunnels

What Per Cent of Carbon Monoxide Can Be Endured with Safety?

By A. C. Fieldner, Supervising Chemist, Pittsburgh Experiment Station, Bureau of Mines

THE rapidly increasing use of motor vehicles and trucks in the United States is creating an entirely new problem in the proper ventilation of tunnels, subways and other confined spaces through which such machines must pass. This problem has become of immediate importance because a tunnel 8,000 feet long is being designed to pass under the Hudson River between New York City and New Jersey. Another tunnel at Pittsburgh, 5,700 feet long through the South Hills, is already under construction, and a third tunnel, 6,000 feet long, between Boston and East Boston, is proposed. It is probable that other tunnels will be started in various parts of the United States in the near future.

The ventilation of such tunnels is a serious matter on account of the poisonous nature of automobile exhaust gases. It is not uncommon to read about finding a man dead in his garage. Generally this happens on a cold winter morning, after he has been running the engine with the doors and windows closed.

The poisonous constituent of automobile exhaust gas is carbon monoxide. It is the same gas which has caused the death of so many miners after mine fires and explosions. It is also found in illuminating gas, and there, likewise, has caused the death of many persons.

Carbon monoxide has no color, taste, or smell. The smoke issuing from the exhaust of an automobile is not carbon monoxide, although where there is smoke there is usually carbon monoxide present. The amount of it present in automobile exhaust gases varies under different conditions of running a machine. Probably the principal cause for variation is the adjustment of the carburetor. A rich mixture may give as high as 10 per cent carbon monoxide in the exhause gases. A very lean mixture will give an exhaust gas containing nothing, or perhaps not more than one or two per cent. All gradations between these percentages occur. For this reason, engineers who have to design the ventilation for tunnels have no accurate information on what the average percentage of carbon monoxide is likely to be.

Very few tests have ever been made on cars taken from the street and tested in the condition under which they were operated, and the only way to obtain this information is to run a great many tests on the road under exactly the same conditions as will prevail in tunnels, using cars and trucks of various sizes, so that average results may be obtained for each type of machine.

METHOD OF CONDUCTING AUTOMOBILE ROAD TESTS.

In order to obtain information as to the amount and composition of automobile exhaust gases, the Bureau of Mines has undertaken to make tests at its Pittsburgh station, on a number of passenger cars and trucks, about 100 in all. The expense of carrying out the work is being borne by the New York and New Jersey State Bridge and Tunnel Commissions, who need the information for designing the tunnels under the Hudson River. Pittsburgh is also contributing to the work by furnishing the necessary cars and trucks for making the tests, as the local need for the information is great, to insure adequate ventilation for the tunnel under the South Hills.

In making the tests an accurately graduated tube containing the gasoline to be used is attached to the carburetor. Another apparatus for collecting the gas sample is attached to the exhaust pipe by means of a rubber tube. The car is taken to the test course and run for exactly one mile at the required speed. During this period the gasoline is accurately measured and a sample of gas is collected. The gas sample is sent to the Bureau of Mines laboratories and is carefully analyzed for all constituents; and from these results the number of cubic feet of carbon monoxide given off by the car is calculated.

Tests are made on a level grade and up and down a three per cent grade, at rates of speed of 6, 10, 15 and 20 miles per hour. Tests are also made with the engine racing, idling, and accelerating, so as to reproduce conditions in a tunnel when it is crowded with cars which are starting up after a blockade in the traffic. Nothing is overlooked in obtaining information which will show the worst possible conditions that might arise in a tunnel.

EFFECT OF CARBON MONOXIDE

The carbon monoxide in exhaust gases is an active poison, for the reason that it unites with the red coloring matter of the blood and prevents it from taking up oxygen from the air. The victim really suffocates in much the same way as if his air supply were shut off. Only very small percentages of carbon monoxide are needed to render a person unconscious. One per cent in the atmosphere will produce death very quickly. I have been in 0.1% carbon monoxide for one hour, and suffered a distinct headache from this exposure.

In order properly to calculate the amount of air that is needed to sweep out exhaust gases from a tunnel, engineers must know what is the largest allowable percentage of carbon monoxide that a person may breathe for several hours without any ill effects whatsoever. This problem is also being investigated by the Bureau of Mines. The work is carried on by Dr. Yandell Henderson, of the Bureau, at the Physiological Laboratory of Yale Medical School, New Haven, Connecticut. He is determining just how many parts of carbon monoxide in 10,000 parts of air may be considered safe.

At the present time authorities differ somewhat in this respect. Practically all of them agree that 1 to 3 parts in 10,000 are perfectly safe for at least an hour. A few authorities believe that even 5 or 6 parts may be safely tolerated. The work being done by the Bureau of Mines should determine which figure shall be used. These tests are made by subjecting a large number of people, who volunteer themselves for test, to air containing these small percentages of carbon monoxide.

VALUE OF TESTS TO OWNERS AND DEALERS

The automobile exhaust gas tests when completed will also be of great value to owners of automobiles and trucks, and also to dealers, as it will furnish reliable unbiased information on the efficiency of a given machine under particular conditions. For example, the tests thus far may have shown no difference in the efficiency of different makes of cars and trucks as regards gasoline economy, but cars of the same make showed large variations, due to the fact that the owners were running the machines with improper adjustment of carburetors. Most of them were using very rich mixtures. In fact, the average of 24 cars tested showed that 20 to 30 per cent of the heat in the gasoline went out in the form of unburned gases in the exhaust. In other words, if the mixtures had been leaner, the owner would have obtained 25 per cent greater mileage from a gallon of gasoline.

Drivers naturally adjust their cars to start easily in the winter time. This means that they will use rich mixtures.

It is expected to continue the automobile and truck tests throughout the summer, in order to find out whether less carbon monoxide is produced when the machine operates in warm weather, and the Bureau of Mines is very anxious that owners of automobiles and trucks continue their coöperation in furnishing cars for test.—U. S. Bureau of Mines, Reports of Investigations.

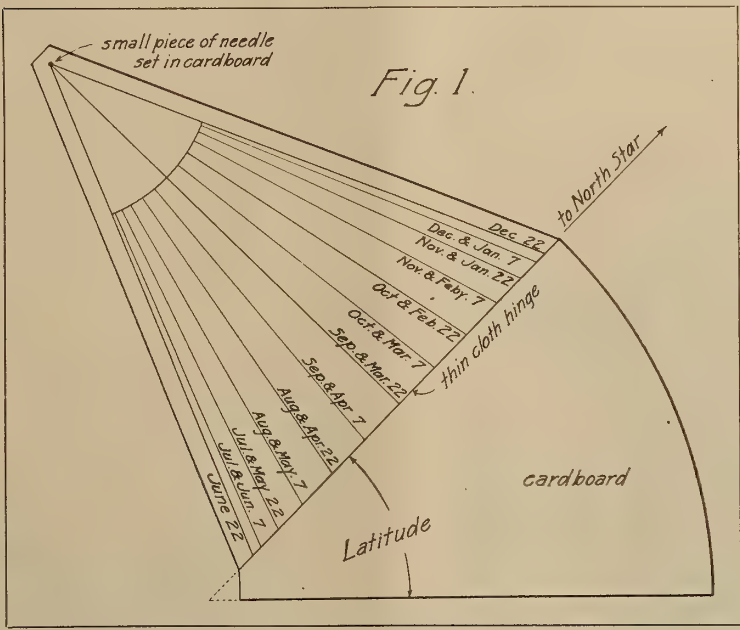
Determining a Meridian from the Sun

A Readily-Made Pasteboard Instrument

By John D. Adams

IN surveying the public lands, the U. S. General Land Office makes use of the usual surveyors' transit equipped with a solar attachment. This device makes it readily possible to determine a meridian with an accuracy of a minute or two in arc—a result, however, that necessitates very close adjustment of the several portions of the mechanism. In its most improved form the attachment is rather formidable in appearance, and in this doubtless lies the reason why so many engineers avoid it and are unfamiliar with its principle of operation.

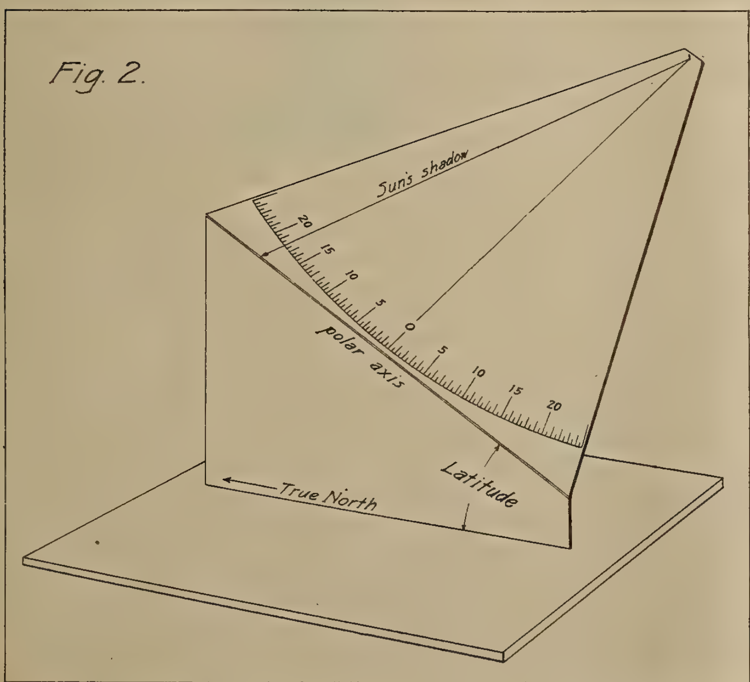
The surest and certainly the most interesting way of gaining a clear and practical understanding of some seeming obscurity is to provide, where such is possible, a working model reduced to mere essentials, the manipulation of which if it does not accomplish more than pages of written text will surely aid in elucidating them. It is accordingly the writer's purpose to present, in place of the telescope, mirror, latitude and declination arcs of the solar attachment, a simple and interesting device, consisting of two pieces of cardboard, with which an approximate meridian may be mechanically determined on precisely the same principle that lies hidden in the highly improved instruments used by the United States surveyors. By making such a device in a somewhat more durable form, a means will be provided whereby a meridian may be quickly determined within a degree—a result hardly to be expected with the magnetic needle with all the uncertainties of local attraction.



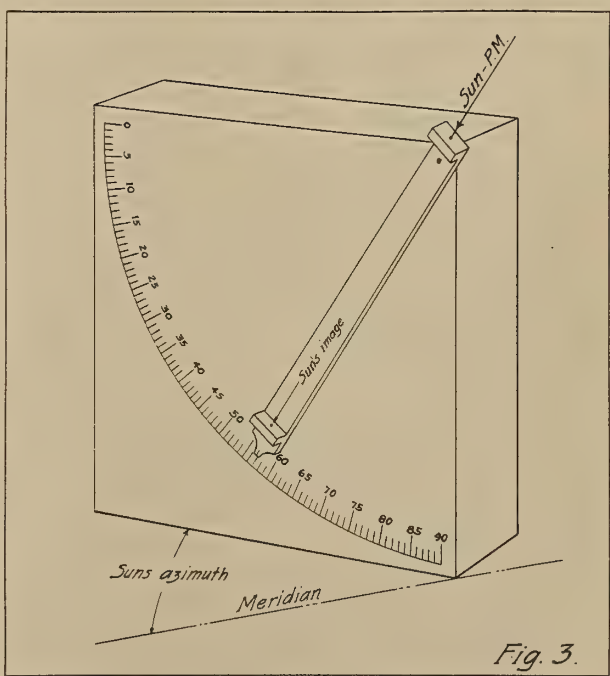
LAYOUT OF THE DEVICE FOR DETERMINING A MERIDIAN FROM THE SUN

From the center point on one side of a piece of smooth, flat cardboard erect a perpendicular from four to six inches long. Using a point near the upper end of this line as a center, draw six radii on the right hand side of the perpendicular making the following angles therewith: 23°-27′; 22°-30′; 19°-53′; 15°-47′; 10°-37′; and 5°-23′. These will represent the sun's south declinations, and should be dated as indicated in Fig. 1. On the other side of the perpendicular draw six similar radii for the north declinations at the following angles: 23°-27′; 22°-41′; 20°-20′; 16°-38′; 12°-00′; 6°-27′, which are also to be date as shown.

Cut another piece of cardboard to the exact angle of the latitude of the place where the device is to be used, and then fasten the two pieces together with a thin cloth hinge. Through the central point of the radial lines tightly insert a piece of sewing needle just long enough to project about one-sixteenth of an inch on each side of the cardboard. At some convenient point where the sun's rays are available, place the lower edge of the lower piece of cardboard on a level surface,

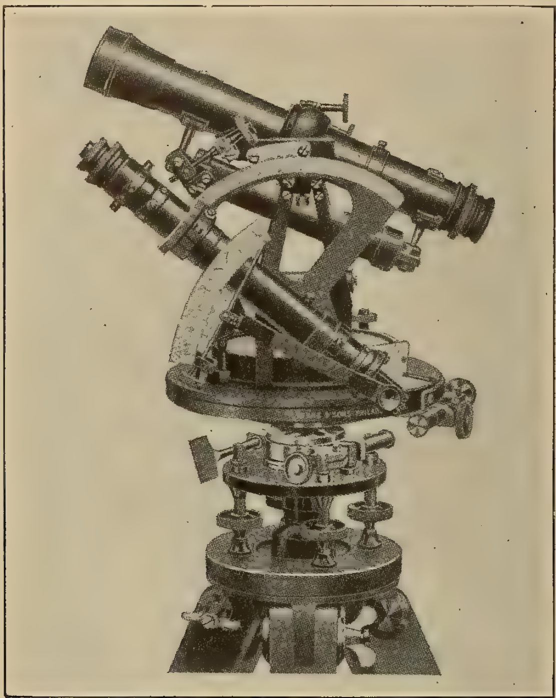


HOW THE PASTEBOARD INSTRUMENT IS MOUNTED



SIMPLE DEVICE FOR "DIRECT SOLAR" OBSERVATIONS

holding the same as nearly vertical as possible with one hand. With the other manipulate the other piece of cardboard until the shadow of the piece of needle lengthens out as far as the hinge, when it will be evident that it is in the plane of the sun's rays. While maintaining this condition, move the whole about on the level surface until the shadow falls on the radius corresponding to the date of observation, when it will be found that the vertical piece of cardboard is in an exactly north and south position. A few trials will show that in no other position will these few simple conditions be met. To demonstrate this, simply set the latitude section in any position but on the meridian, and it will at once be found that at no possible angle of the hinge will the sun's shadow lengthen out across the proper date line.



MOUNTAIN SOLAR TRANSIT, SHOWING ENLARGED LATITUDE AND DECLINATION ARCS

If it is desired to make the experiment in the afternoon, draw radial lines on the side shown in Fig. 1; if in the morning, the other side should be used, as in Fig. 2. In common with the modern solar attachment, the best results cannot be obtained within two or three hours of noon, a fact that is not due to any defect in principle, but to the smallness of one of the angles in the involved spherical triangle.

As our years are not all of the same length the sun's declination is not always the same on identical dates, in consequence of which more accurate results may be obtained by replacing the date lines with a declination arc on either side of the center line. By consulting the current ephemeris of the sun, the exact declination may be determined and then indicated on the arc by a light pencil mark, through which the sun's shadow may then be caused to pass. By means of a metal protractor having a projecting arm, it is a comparatively simple task for a draftsman to lay out the necessary scale to at least half degrees.

It should be understood that the accuracy of the results depends to a certain extent on having the horizontal surface quite level, a condition, fortunately, that is easy to attain with a piece of board and a small level. Though not so important a condition, the latitude sector should be held vertical, but those who wish to make use of the device for practical purposes would, of course, dispense with the cardboard entirely and construct a base of substantial width that would always stand vertically. The latitude sector could be made adjustable, the cloth hinge replaced by pivots, and other improvements would doubtless suggest themselves.

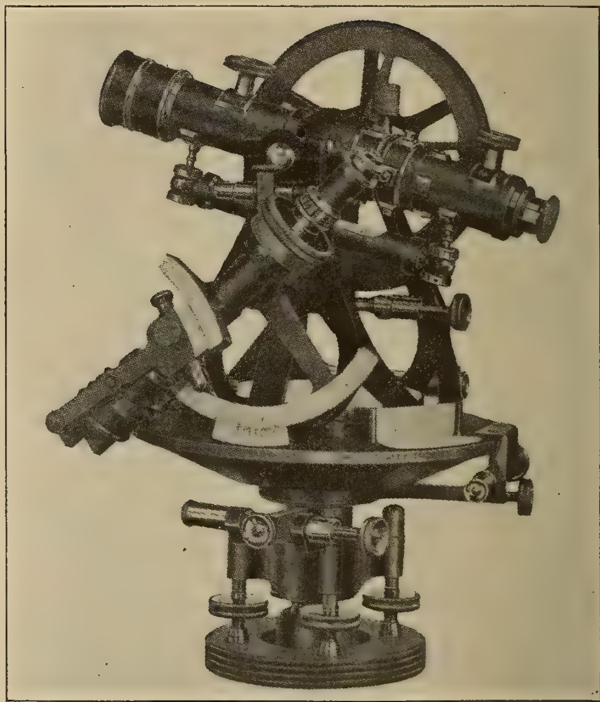
It is not the purpose of this article to go into the theory of the solar observation, as those who are interested can find it duly expounded in standard works, but it is hoped, after a little experimenting with the cardboard model, that what had previously appeared a very abstruse matter, necessitating a complicated mechanism and elaborate mathematical treatment, is essentially a very simple idea.

In this connection it may be well to refer to another form of solar observation, also used by the U. S. General Land Office, called the "direct solar." The sun is observed through the main telescope of the transit, and its altitude in a vertical plane measured. Its azimuth is then calculated by means of the following formula:

$$\text{Cos Azimuth} = \frac{\text{Sin Declination}}{\text{Cos Latitude} \times \text{Cos Altitude}} - \text{Tan Latitude} \times \text{Tan Altitude}$$

For south declinations the sun's declination is considered negative. If the algebraic sign of the result is positive, the azimuth is referred to the north point; if negative, to the south point.

In this form of observation the involved spherical triangle is solved mathematically, whereas with the solar attachment the solution is effected mecanically. By means of logarithms the above formula is reduced very quickly, and in taking a set of several readings it will be noted that all but the two terms involving the altitude may be considered constant.



PRECISE TRANSIT WITH TELESCOPIC SOLAR ATTACHMENT

An interesting and simple means of experimenting with this form of observation for meridian is illustrated in Fig. 3, and although only paper and wood enter into the construction it is readily possible to determine thereby a north and south line with an error of less than thirty minutes. A well seasoned block about five inches square and an inch and a half thick should be procured from the mill, where facilities are always available for securing a high degree of accuracy in sawing. On one surface only a paper protractor, reading to thirty minutes, is to be attached by means of glue—the glue being applied to several small spots rather than to the entire surface to prevent warping. In placing the protractor, set the block on a perfectly flat surface, and line up the 90° mark with a steel square, which may also be used to determine whether the surface of the protratcor stands at right angles with the horizontal surface. This condition is important, and any slight adjustment that may be necessary may be made by pasting on a narrow strip of paper along the proper edge

of the base. Prepare a small radial arm of the form illustrated, and in the upper projection drill a hole about the size of a pin, so that the sun's rays may pass through and illuminate a small spot on the lower projection. This arm is attached to the block by means of a pin or small nail near the upper end put in at the exact center of the protractor. Set the arm at 90°, and with the steel square resting on the same horizontal surface as the block, make a small dot on the lower projection of the arm to indicate where the sun's image should fall.

To determine a meridian, carefully level up any convenient flat surface, on which the block should be moved about until the surface of the protractor is in the plane of the sun. Adjust the angle of the arm until the image falls on the small indicating dot, then record the sun's direction by drawing a line with a sharp pencil on the horizontal surface using the lower edge of the block as a ruler, after which read the altitude. The above formula will then give the relation of the sun to the meridian, which may be laid off with a protractor set on the line prveiously drawn.

By consulting an ephemeris it will be seen that for practical purposes the exact time is not a matter of great importance. To avoid the necessity of interpolating with the eye in reading the altitude, one may follow the sun for a minute or two until the reading is an exact division on the arc, when the mark may then be made on the horizontal surface. This may be repeated several times in a few minutes, and the mean of all the results taken.

A very convenient ephemeris of the sun and Polaris may be had from the Superintendent of Documents, Government Printing Office, Washington, for five cents.

AN IMPROVED TOWING SPAR WHICH CAN BE USED AS A NAVIGATIONAL INSTRUMENT.

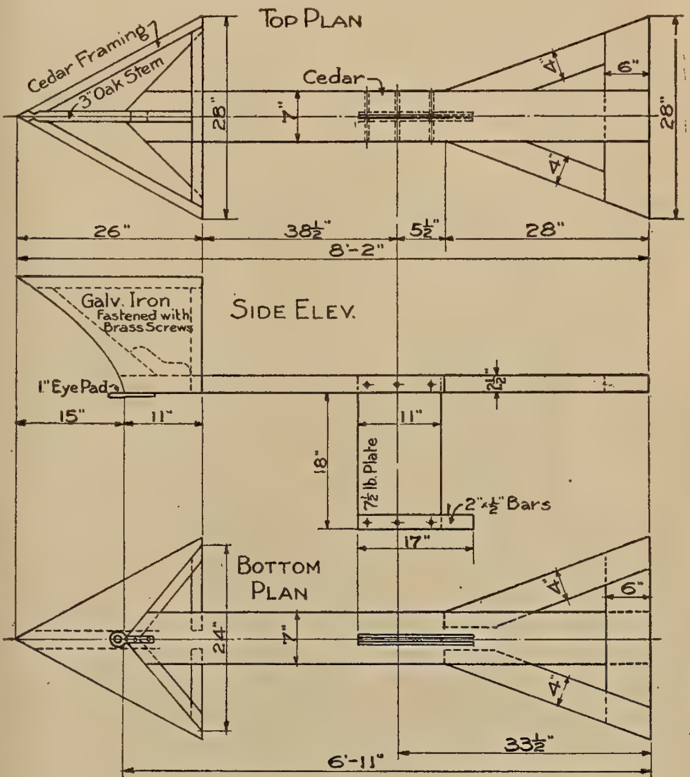
By Lieut. Commander S. F. Heim, U. S. Navy.

In these days of radio compasses and gyro controlled artificial horions, it might be considered rather late to offer a scheme for taking sights by bringing the heavenly body down to a spar towed by the ship. The writer has read in the U. S. Naval Institute Proceedings of sights being taken on the waterline of another ship, on a boat sent out by the ship and even on a chip log astern of the ship, but never on a towing spar which would seem to be the logical method because it can be let out from the ship without stopping or altering speed and its distance from the ship can be controlled accurately by marks on the tow line.

The scheme seemed so simple and plausible that the writer wondered why it had not been done before and he inquired of experienced officers and searched the files of the Naval Institute but failed to find where it had ever been tried. To test his theory he went out in the bay off Greenbury Point on a submarine chaser and steamer both day and night and took sights, using an ordinary towing spar with only 350 feet of line. A small waterproof storage battery light was attached to the spar at night. The results of these trials were accurate far beyond expectations. These results in altitude difference by Marcq Saint-Hilaire method were accurate within 1 minute of arc.

Of course it is realized that conditions here were ideal, with no wave movement of either the spar or the ship; but it is proposed to eliminate these errors as far as practicable at sea by use of the improved towing spar which will remain afloat with 500 or 600 yards of line out from the ship. The longer the length of line the more accurate will be the results. The maximum possible error due to rising and falling of spar in sea will be the angle with tangent equal to maximum rise divided by length of tow line. Thus with a 3-foot rise and fall of spar with 600 yards of line the maximum error would be 5 minutes in altitude.

The three views of the towing spar are self-explanatory and a description is unnecessary. This spar was developed and used by the commanding officer of the "U. S. S. Charleston" while engaged in convoy duty during the war. The old navy towing spars and special sheet metal tank spars supplied to ships were useless for this work because they would tow under at the distances at which they were desired to be used. The towing under was caused by two things: their shape and the towing line. The improved spar shown in sketch was towed by a small wire rope of about the diameter of a lead pencil. This wire line was wound on a small reel secured just forward of the quarterdeck winch. The spar was hauled in by means of the deck winch. It was found that manila line was unsatisfactory for towing spar work because the waterlogging and friction tend to pull the spar under. It will be noted that a strong keel or centerboard is attached to the spar. This is an important feature which causes it to tow during turns and prevents capsizing.



TOWING SPAR USED ON THE U. S. S. "CHARLESTON"

By having at hand a table of "dips" to use for different speeds and lengths of tow line, the operation of taking a sight would be comparatively simple. He could take the bearing of the heavenly body to be observed and then head the ship directly away from the body and with spar out take a series of sights. The average of the series should be taken to counteract the errors due to wave heights of the spar. By practice in fair weather when the "dip corrections" are computed he could determine the limits of accuracy and how much confidence to place in it when occasion for its use arrives. We have all experienced the occasion when a sight was highly desirable or even necessary with the sun out or stars shining but no horizon visible.—Copyrighted by the U. S. Naval Institute. Reprinted by permission, from the *Proceedings* of the Institute, March, 1920.

CONCRETE PONTOONS FOR SHIP SALVAGE.

A set of reinforced concrete floats have been built by Messrs. Christiani and Nielsen says *Le Génie Civil* (Feb. 21, 1920) for the salvage of ships. The floats are cylindrical and measure 21 meters long and 3.60 meters in diameter. Each float has a bearing capacity of 100 tons and is designed to lift 200 tons. It can withstand an external pressure 2 kg. per cm^2 and in exceptional cases 4 kg. per cm^2 so that it may be used at depths of 40 meters.

SELENIUM AND TELLURIUM.

TWO "RARE ELEMENTS" WITH POSSIBILITIES.

BY VICTOR LENHER,

Professor of Chemistry in University of Wisconsin, and Member of the National Research Council's Committee, on the "Uses of Selenium and Tellurium."

The National Research Council is a co-operative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

THE two "rare elements," selenium and tellurium, which are in many respects similar to sulphur, are not so rare as in generally supposed. Indeed the term "rare element" is in general a rather vague and indefinite expression. For example, titanium is commonly regarded as a rare element, although F. W. Clarke has shown it to be more plentiful than carbon, sulphur and phosphorus combined. Titanium is, therefore, very plentiful, but the number of its chemical compounds is very limited.

A recent estimate of the amount of selenium and tellurium that can be produced at present in the United States, without making any material additions to the present plants, has shown that this country can furnish annually more than 300,000 pounds of selenium and about 125,000 pounds of tellurium. The elements are marketed commonly in elementary form although some of the refineries have produced small quantities of derivatives, such as sodium selenite and tellurium dioxide.

The general chemical characteristics of these two elements closely follow those of sulphur, indeed the types of selenium and tellurium compounds are in general those of sulphur, but due to their higher atomic weights they are more metallic. Tellurium in elementary form looks much like antimony. It is white, strongly crystalline, so strongly crystalline that it is quite brittle and can be easily powdered. Toward the acids it is as refractory as antimony. Toward alkaline solutions it is strongly resistant while in water or in moist air, it does not rust or corrode appreciably. It is known that antimony can be electroplated and gives a durable plating. It would be interesting to study tellurium in this direction. A systematic study of the available electrolytes that can hold tellurium in solution could be carried out advantageously. Antimony has been successfully used for many years in antifriction alloys and is an essential constituent of stereotype metal. No recorded study is known of an attempt to utilize tellurium in these alloys. The whole field of the metallic alloys of tellurium needs to be studied carefully, and, unquestionably, an element whose general characteristics are so close to antimony will almost certainly be found to be a useful metal instead of as at present having no practical applications.

Another metallurgical line which has not been studied in any detail is the action of these two elements in the iron and steel industry. The effects of sulphur and phosphorus on iron and steel have been very carefully studied. The objectionable phosphorus has been most scrupulously removed by the basic open-hearth process as a result of years of study and observation, yet today we are actually adding iron phosphide to open-hearth steel, which is to be used for certain purposes, to bring up its phosphorous content. It is interesting to contemplate what careful experimentation would develop on the influence of selenium and tellurium on the various grades of steel.

Selenium in the so-called metallic form has long been characterized by its unique action toward light. Its conductivity of the current varies so greatly when brought from the dark into the light that this peculiar property of its conductivity, varying as it does, directly proportional to the intensity of the light, has caused the development of the selenium cell. This cell, or, in reality, a resistance apparatus, has found numerous uses at various times, such as automatically turning off city gas lights at daylight. It has been used in lighting and extinguishing the lights in light buoys, in army signalling of various kinds based on the heliograph principle, as a control in chemical processes such as the contact sulphuric acid manufacture, and in the wireless telephone.

It has been known for a long time that selenium gives to glass a red color. This principle during the wartime was made use of in the decolorization of glass owing to the shortage of manganese which had been hitherto used largely for this purpose. Selenium is introduced into the glass either in the elementary form or as a salt of selenium. The rose color which selenium imparts to the glass is not exactly the complement of the green of the ferrousi ron hence it is common practice to add a small amount of cobalt oxide along with the selenium. Since both selenium and its compounds are very readily volatile at such temperatures as are used in glass making, a large amount of the selenium decolorizer is volatilized. The loss of selenium is therefore high, and as a consequence selenium can only be used to decolorize glass when the glass manufacturers are willing to pay the higher cost price. During the war when the supply of manganese was limited selenium was used extensively in glass decolorizing, but as soon as shipping was resumed and manganese again became available, the use of selenium in the glass business fell to almost nothing.

There are a number of possible uses that suggest themselves for these elements, none of which has received the attention that it deserves. Lithophone, the intimate mixture of barium sulphate and zinc sulphide made by bringing together barium sulphide and zinc sulphate, is full of suggestions. Various colored lithophones can be produced by using an antimony sulphate liquor with barium sulphide when the white barium sulphate produced is colored by the orange sulphide of antimony. Similarly cadmium or arsenic liquors give a corresponding yellow lithophone. The substitution of selenium and tellurium in lithophone is very suggestive inasmuch as it should be possible to replace the sulphur of either the sulphate or that of the sulphide by either of these elements. The selenate and tellurnate of barium are white and insoluble like the sulphate, while the selenides and tellurides like many of the metallic sulphides are variously colored.

The uses of the various compounds of selenium in medicine have received some attention, but the derivatives have had almost no systematic study. Professor W. J. Gies, of Columbia University, in a very careful study has shown that tellurium compounds have a physiological action quite similar to that of arsenic, but that the toxicity is much less than that of arsenic. The selenides and tellurides as well as the oxidized salts have been experimented with in cancer, tumors, and syphilis, but their efficacy is more or less questionable. These few compounds, which are of the simplest chemical character,

are almost the only ones of which any experimental results are recorded. When one considers the vast field of important and valuable sulphur-containing organic compounds ranging from saccharin to sulphur and in the arsenicals from Fowler's solution to salvarsan, it would seem that there exists an almost virgin field for research by the physiological chemist. When one thinks of the physiological action of the derivatives of tellurium as medicinals, the offensive garlic odor of the "tellurium breath" is brought to mind. This will unquestionably act as a deterrent in the minds of some, but should certain physiological actions be found, they might be so valuable as to overcome the objections due to the characteristic methyl telluride odor.

In the vulcanization of rubber a few experiments are recorded which seem to indicate the similarity of the action of selenium to that of sulphur. Much more remains to be done especially along the lines of the use of the chlorides or bromides of these elements as accelerators. Tellurium and its derivatives have received practically no attention in the rubber industry. Possibly from the nature of the organic materials present, the objectionable methyl telluride again would militate against its use.

A relatively small amount of research has been conducted with selenium in the dye industry while almost nothing has been done along these lines with tellurium. One of the first lines that would naturally occur to one would be the substitution of selenium for sulphur in the so-called sulphur colors. These are among our cheapest colors. There are at present two serious obstacles in the replacement of sulphur by selenium in the sulphur colors. The first is the relative cost of selenium to that of sulphur. The second is the nature of the bath which in the present development of the sulphur color process would make the cost prohibitive. There is, however, the possibility that a brilliant and fast color of considerable intensity could be found which could be manufactured profitably. The field of synthetic dye-stuffs does, however, possess great opportunities for experiment and is almost undeveloped.

The utilization of the less common elements has always been a problem which has interested chemists. Not many years ago elementary silicon was sold at a high price per gram and even then it was almost a curiosity to be found wholly in museums, yet in combined form it comprises one-fourth of the crust of the earth. Today silicon in elementary form is produced in large quantities at a few dollars per ton and is used on a large scale in deoxidizing non-ferrous alloys. Similarly a few years ago, tungsten was known only as a gray metallic powder with no other uses than that of the formation of the self-hardening steels. Today the use of malleable tungsten wire in the lamp bulb and of the sheet metal in the spark coil to replace the more expensive platinum, makes metallic tungsten a very important commercial product. Along the same line molybdenum, tantalum, and the oxide of zirconium are substances which until recently were only museum specimens but today are very useful products. Only a few years before the war, large money prizes were offered in Europe for methods of utilization of bromine and of boron. We well know how valuable an element bromine was during the war and of its large consumption since the war, particularly in organic synthesis.

All of the elements which nature has furnished to us must find their place as a useful necessity to man. It is indeed incomprehensible to think that in the entire chemistry or physics of one or more elements there cannot be at least a single compound or property that can be utilized by mankind.

Except for the wartime use of selenium in the glass industry, the present uses for selenium and tellurium are very limited. A few hundred pounds of each would supply all demands. The large amounts of these elements which are available today and for which there is no practical use, have caused the National Research Council to create a committee on the Uses of Selenium and Tellurium. This committee, consisting of A. E. Hall, Chairman, with H. G. Greenwood, Victor Lenher, O. C. Ralston, E. W. Rouse, S. Skowronski and A. W. Smith, has been working in close contact with the producers of selenium and tellurium in the United States, and it has been possible to make arrangements whereby large quantities of these elements can be secured at a very low figure for experimental purposes. The Raritan Copper Works, Perth Amboy, N. J., the U. S. Metals Refining Company of Chrome, N. J., the American Smelting and Refining Company, Omaha, Nebr., and the Baltimore Copper Smelting and Rolling Company, Baltimore, Md., which includes all of the producers of these elements in this country, will furnish workable quantities of these elements for research purposes at cost price.

Mr. E. W. Rouse, of the Baltimore Copper Smelting and Rolling Company, will ship at any time reasonable quantities of selenium to investigators gratis, upon the recommendation of the Committee of the National Research Council on Uses of Selenium and Tellurium, and Mr. Arthur E. Hall of the Omaha Plant of the American Smelting and Refining Company, will forward reasonable quantities of tellurium, gratis, under the same circumstances.

THE SEARCH FOR CEREALS.

By H. E. Howe, Vice-Chairman of the National Research Council's Division of Research Extension.

Notwithstanding the still unsettled question as to whether heredity or environment exercises the greatest influence upon an individual, it seems certain that both play a very vital rôle in plant life, particularly in the more useful plants, such as wheat, which we have had occasion to study somewhat intensively. Unfortunately, under the circumstances which produce the survival of the fittest, we can hardly secure the varieties necessary to guarantee maximum production in the various wheat areas of so large a country as the United States. Our occasional severe winters lead to the abandonment of large areas, and under these severe conditions the entire acreage in a particular locality is very apt to be wiped out, so that we have no survival which will produce seed to withstand other unusually hard winters. Statistics tell us that during the past five years a total of thirty million acres of winter wheat have been abandoned in this country, which, at the average yield of fifteen bushels, means a loss of four hundred million bushels of wheat, with a corresponding monetary loss—and, more important, a loss of food to the world.

It was to improve conditions of this sort, as well as to introduce new cereals from foreign countries, that some time ago Dr. M. A. Carleton, then of the Bureau of Plant Industry of the U. S. Department of Agriculture, began a systematic collection of cereals from foreign countries for the purpose of introducing new strains and varieties quite different from the species to be found ordinarily in North America. To what extent this work was successful may be indicated by the following:

Wheats used in the production of macaroni and the like must be unusually high in gluten. Previous to 1902, wheat satisfactory for this use was not produced in important quantity in the United States. Some years before that, a new form, now called durum wheat, was obtained from a semi-arid district in East Russia, and introduced in similar districts in our country, where other kinds of wheat do not succeed. Regular grades of this wheat were established at the different boards of trade following the harvesting of the first crop of any importance, which was, as indicated, in 1902. By 1908, our annual exports of this variety had reached twenty-seven million bushels, all of which were sent to Europe, where there is a constant demand for wheat possessing the characteristics of the durum variety.

In April, 1913, No. 1 durum wheat sold at a premium of 8½c a bushel at Duluth and 6¼c at Minneapolis over our No. 1 northern wheat. At the present time, the average crop of this variety is approximately fifty million bushels a year, and in the last two years its popularity has increased. Our Ca-

nadian neighbors have also adopted the variety. The original seed obtained in Russia was less than three hundred bushels. It will be seen at once that the result of this piece of research can be measured in millions of dollars annually, this wealth having been added to that of our farmers, grain dealers, millers, macaroni makers, and the public at large.

Another valuable variety introduced through the efforts of Dr. Carleton is the Kharkov hard winter wheat. The yield of winter wheat is much heavier than that of spring wheat in the same locality, but the winters in the great plains north of Kansas, and indeed in some part of Kansas, are too severe for any American variety. About twenty-five years ago the Russian Mennonites introduced Turkey wheat into Kansas, bringing it with them from South Russia, and later Dr. Carleton imported a large quantity of seed wheat from North Taurida, Russia, which helped the Kansas situation. In 1900, however, the Kharkov wheat, still hardier than earlier varieties, was secured from South-Central Russia, in the Starobesk district of Kharkov Province. The extensive use of this variety has resulted in the extension of the winter wheat area into Montana and portions of Minnesota and the Dakotas. Simultaneously, the growing of all hard winter wheats was encouraged because of their hardiness and their rust resistance. Of our present yearly production of from 200 to 400 million bushels of hard winter wheat, there is an average of one hundred and fifty million bushels of Kharkov variety, and the introduction of this strain has again been a benefit to all who produce, handle, or use the grain. Hard winter wheats are considered among the best in the world for milling, and are chiefly grown in that area which uses Galveston as its export outlet. This wheat also supplies the large Kansas mills, and is grown from Oklahoma to Nebraska, eastern Colorado to Iowa and the southern portions of Minnesota, South Dakota and Montana.

Simultaneously with this notable work, new varieties of oats, millet, and rye have also been brought to us. Swedish select oats have been introduced from northern Russia, and this has practically guaranteed the oat industry in some of our northern states. This variety has added more than two million dollars a year to the value of the Wisconsin crop alone. It was developed in Sweden, hence its name, and was introduced in the United States after years of acclimation in Russia and Finland. The early variety of oat, known as sixty-day oats, which really matures in ninety and not sixty days, has been invaluable to South Dakota, and in general to the north-central states east of the Rocky Mountains. It was brought to us from Poltava Province, Russia, and is perhaps the widest known variety of oats in the United States.

The *proso* or Russian millet was introduced from East Russia, and has been found well adapted to Montana and Dakota conditions, yielding much better crops in dry seasons than do other varieties. This millet is used as a breakfast food in Russia, but in this country it is fed to hogs, sheep, and chickens. It has been an important stock food in the drier districts of the northwest. The Kursk millet comes from a Russian province bearing the same name, and the kernels are considerably larger than those of the usual millet. Unlike the common millet, Kursk millet can be fed to stock with little or no bad effect upon the alimentary tract.

The use of rye in food is probably a new thought to many who are otherwise familiar with this grain. Two new varieties of rye successfully established in this country have come, one from Italy, which is remaking the rye industry in the southern states, and the other from Germany, which, as we might expect, has prospered in Wisconsin.

From the above, it would seem that the search for cereals had indeed been well prosecuted. But there is still a great deal to be done, and at the present time there is need for thorough-going research on wheats which will include not only the determining of their present status in the United States, but which will consider many of the other varieties throughout the world for the purpose of still further improving the crop here. The National Research Council is particularly interested in this undertaking, and at the present time is considering the means for continuing the search for cereals. We still need hardier winter wheats for our northern great plains and our northern central states. There are parts of the world where grain is still harvested with the cradle, and frequently the crop thoroughly ripens before the harvester reaches all parts of the field. The result is that, through many centuries, early non-shattering wheats have been developed, and these we urgently need for California and the northern Pacific coast states. Improved varieties of early spring wheats would be of great economic value for Minnesota, North Dakota, and Montana, and early maturing winter wheats should be sought for our eastern and southeastern states. California and Arizona are interested in early wheats, while our great plains and Pacific coast must have more drought-resistant wheats. Still another addition would be rust-resistant wheats for all these various areas.

In plans now being developed it is contemplated that when support has been guaranteed for this work, which is estimated to require ten years' time, visits will be made to European Russia and Siberia, Turkestan, North Africa, India, Australia, Abyssinia, Italy, Arabia, Persia, Roumania, the Balkan States, China and Japan, going out among the farmers, and gradually finding and securing samples of wheats with the desired characteristics. These samples would then be sent to the United States, where wheat nurseries, established and conducted in coöperation with certain agricultural experiment stations, would gradually raise seed from the new varieties for larger and larger experimental plots. Ultimately there would be sufficient seed to introduce on a commercial scale, and with successful variety there would be no question that its use would rapidly spread.

This, then, is a project which directly affects a large number of our people, and which can be carried on in coöperation with many agencies. From past performances, it is safe to predict that such work, if properly supported and carried through to conclusion, will be sure to yield unusual returns and be a notable instance of the type of constructive work which science can perform.

ETHYL CHLORIDE.

ALBERT HENNING discusses the technical application of ethyl chloride in the Journal of the Society of Chemical Industry, transactions, 1920, Volume No. 39, pointing out that commercial ethyl chloride is not poisonous and is not more inflammable than benzine or methylated spirit. The material is useful in the production of dyestuffs and pharmaceuticals, as a local or general anaesthetic, for solvent purposes, and as a medium in refrigeration. In its use there is no need for high pressure apparatus since it liquefies at 30° Centigrade at a pressure of 12 pounds. Ethyl chloride is the cheapest ethylating agent and is a particularly good solvent for simple organic compounds, fats, and oils, for which it may be used in extraction. When more complex compounds, such as those containing several hydroxyl groups, are concerned, solvent action is very slight, if indeed such compounds are dissolved at all.

Ethyl chloride is the best refrigerant for use in domestic refrigerating machines, the use of which is extending. Its advantage is that it may be used at a low pressure, which need not exceed 15 pounds per square inch. When a spray of ethyl chloride falls upon a small object its temperature may be brought as low as 30° below zero Centigrade. Its use as a refrigerant is also recommended for larger installations and in most instances the circulation of cooled brine may be dispensed with, circulating the ethyl chloride instead.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

FISH SCALING IN ENAMELS FOR SHEET STEEL.

THE jumping off of small particles of enamel which results in the defect known in shop practice as "fish scaling" is probably the most serious defect to which enamels for sheet steel are subjected. It occurs intermittently in practically all the plants manufacturing this class of material in this country and entails losses running into millions of dollars to the manufacturers. At the request of the Metalware Manufacturers Association of America, the Enameled Metal Division of the American Ceramic Society, and a large number of individual manufacturers, the Bureau is carrying on a comprehensive research in an endeavor to discover the cause or causes of this defect and the methods of controlling and eliminating it. This investigation was begun in July, 1919, and has been conducted energetically ever since.

Up to the present time, the Bureau has made ninety melts of enamel comprised of 21 different compositions. These have been subjected to various treatments in firing and melting and have been applied in various ways to several kinds of steel. In all, over 4,000 sample enameled plates have been made up to date. This work has demonstrated that one of the most important factors in the production of fish scaling is too severe heat treatment in the firing of the enamel. Excess heat treatment may consist of firing the enamel at too high a temperature or of holding the enamel in the furnace for too long a time at a given temperature. Other important factors are the composition of the enamel, the physical and chemical characteristics of the underlying metal, the method of melting the chemical mixtures used in making the enamels and the shape and weight of the metal pieces that are enameled. These various factors have been investigated to a certain extent in this work and will be studied more thoroughly as the investigation progresses.

The data obtained in this investigation up to the present time have enabled the Bureau to be of very material assistance to several manufacturers in eliminating this trouble. It seems very probable that the completion of the investigation as now planned will definitely eliminate fish scaling, and likewise settle the interesting question of what is the physical basis of the phenomenon.

RELATION OF COMPOSITION OF ENAMEL TO SOLUBILITY IN ACIDS.

FOR several months the Bureau has had in progress an investigation of the relation of composition of enamel to solubility in strong mineral acids. The need for this investigation was clearly demonstrated during the war by the difficulty manufacturers of acid-resisting enameled wares experienced in meeting the requirements of chemical manufacturing plants. The manufacturers of enameled kitchen wares are also interested in this problem.

Up to the present time 33 enamel compositions have been melted and tested. While the problem is a large one and the investigational work will necessarily be continued for some time, results so far obtained indicate that some of the commonly accepted conceptions of the relation between composition and acid resistance of enamels are erroneous. The chief of these misconceptions seems to be that oxides which are similar in nature chemically will have similar effects when incorporated in enamel compositions. That this is not always true is shown by the fact that calcium oxide tends to produce enamels with very low resistance to attack of acids while barium oxide produces quite resistant enamels. In connection with the gathering of data on the chief object of this investigation, information is being secured in regard to relations of composition to their fusibility and to the tendency to chip or to craze, or crack. It is expected that as a result of this investigation the Bureau will be able to advise manufacturers of acid-resisting wares as to the methods and compositions to be used in producing wares of this class superior to any now being made, and also that it will enable the Bureau to be of material assistance to manufacturers of enameled ware for culinary purposes. As a matter of interest, it may be stated that as a part of this investigation an enamel has been produced which appears to duplicate in composition and working properties the best grades of French acid-resisting enamel.

SUBSTITUTES FOR ANTIMONY OXIDE IN GRAY COAT ENAMELS.

IN certain quarters there is objection to the more or less common practice of using a small amount of antimony oxide in one coat enamels on utensils intended for culinary purposes. This objection is based on the rather hypothetical assumption that such enamels may be slightly poisonous. Although the Bureau believes that this is probably not the case, at the request of several manufacturers of this type of ware, it has undertaken the investigation of possible substitutes for antimony oxides for making such enamels.

NEW INSTRUMENT FOR DETERMINING COEFFICIENTS OF REFLECTION.

IN the design of lighting installations and in the case of many other applications of illuminating devices, a knowledge of the value of the coefficients of reflection of walls, ceilings, or other objects may be of material assistance. The illuminating engineer, with the aid of tables and instructions issued by one of the lamp manufacturers in this country, can predict with a fair degree of certainty the illumination which will be produced by any given type of lighting installation if he knows the shape of the room and the light reflecting characteristics of the walls and ceilings.

At the present time there is no instrument available outside the laboratory which will enable the engineer to measure the coefficient of reflection of surfaces. Even when the measurements are made in the laboratory, the process is very difficult and tedious, and subject to rather large uncertainties. Several methods have been used, but most of them have given incorrect results because of an error in the value assigned to the standard surface used.

In order to remove the uncertainty in the value assigned to the standard surface and to develop an instrument which could be applied to the measurement of surfaces in place, a new instrument has been developed after extensive experiments, and a much better standardization of a reproducible surface has been made. This instrument is light and portable, and can be used with any one of a number of types of portable photometers, giving results which are reliable.

The instrument which has been developed is called a reflectometer. Aside from the photometer, which measures the light intensities, it consists of a small metal sphere from which a segment has been removed, leaving about nine-tenths of its original surface. It is painted inside with a diffusing white paint, and a beam of light is projected through a small hole in the wall onto the surface which is to be tested. The test surfaces may be compared with a standard surface or with a flat surface painted with the same paint as the sphere. It is believed that this reflectometer will fill a very real need.

GENERATING SETS FOR RADIO LABORATORY USE.

The researches and tests in progress in the radio laboratory require the use of steady sources of alternating current of frequencies from 200 to 10,000,000 cycles per second. Several generating sets have been designed and constructed in which electron tubes and associated circuits are used to produce alternating current of the required frequency from a direct current power supply.

One of these generating sets, having a wave length range of 30 to 50,000 meters (frequency range of 10,000,000 to 6,000 cycles) has been built up with a convenient control panel for use in standardizing wavemeters and other radio apparatus.

Another generating circuit, for use in the study of insulating materials, is designed with special inductance coils and a special condenser with a scale which gives the power loss in the sample of insulating material directly, without any calculation. This generating set is supplied with power from a 600-volt storage battery of small capacity which is arranged in especially convenient form for charging, refilling, and the special care which small storage cells require.

Two low-power generating sets have been designed for portable use and are especially compact. One of these generates current at a wave length of 30 to 2,000 meters. It has six sets of inductance coils, and a variable air condenser in parallel with which a fixed mica condenser can be connected. The other set generates current of 2,000 to 8,000 meters, using three sets of inductance coils and a single variable air condenser.

An electron tube is also employed in a set for generating audio-frequency currents from 200 to 6,000 cycles which is used for alternating-current measurements, studies of telephone receivers, and other work at telephonic frequencies.

A special generating set for producing small measured voltages at radio frequencies of 200 to 4,000 meters wave length is used for measuring amplifiers and detectors. It is so arranged that the instruments which are being measured are completely shielded from both electrostatic and magnetic fields from the generating circuit, the coils of which are wound in a special way, the entire circuit being enclosed within a copper shield.

THE CATHODE-RAY OSCILLOGRAPH IN RADIO RESEARCH.

Radio communication utilizes electric currents which alternate so rapidly that no mechanical system can follow the alternations. Consequently, the currents used in radio cannot be studied by means of the ordinary kinds of oscillographs used in other electrical work. It is very desirable to have an instrument which will follow the current in all its alternations and fluctuations, so that the wave form can be accurately traced out. This makes it possible to determine how radio apparatus will act when these currents are used, thus making improvements in design possible.

This is accomplished by the cathode-ray oscillograph, in which a beam of cathode rays is deflected in a vacuum by the action of the electric currents. This beam illuminates a fluorescent screen, and the motion of the light over the screen shows how the current is varying.

Most investigators are familiar in a general way with the principles of operation and the utility in electrical research of the cathode-ray, or Braun, tube. However, there has been very little development and constructional work done on these tubes in this country, chiefly for the reason that, except during the period of the war, cathode-ray tubes could be imported from Germany more cheaply than they could be made here. The price of a cold-cathode tube at present is about 60 marks, in Germany, according to recent quotations. Hence, it is not surprising that rather meager information has been published in America concerning the general principles of design of such tubes.

The results of a study of the design of cathode-ray tubes were given by a member of the Bureau's staff, at a recent meeting of the Institute of Radio Engineers. The device can now be designed and constructed with a considerable degree of certainty to suit a variety of different operating requirements. It is a valuable aid to the standardization of wave meters, and to the determination of wave form produced by spark and other types of radio generators. Its most conspicuous usefulness is in the study of the characteristics and behavior of electron tubes. In studying the performance of electron tubes as detectors and generators of current for radio purposes and their functioning in radio telephony, the cathode-ray oscillograph is a most powerful aid. As an implement of research, permitting visual observation of phenomena previously unseen and furnishing data for new ideas and new theories, the cathode-ray oscillograph performs a service that can be achieved by no other device.

The results of the Bureau's work on the design of these tubes will be available later as a Scientific Paper.

APPLICATION OF ROTARY DISPERSION METHODS TO COLORIMETRY, PHOTOMETRY, AND PYROMETRY.

For about 8 years studies in the application of rotatory dispersion methods to colorimetry and related subjects have been under way at the Bureau. The method proves to be of fundamental importance and in order that it may be more generally understood and put to practical use, a series of papers relating to it are being prepared for publication. A general paper outlining the subject and giving a resume of work already accomplished was presented to the Optical Society of America, and will be published in its journal.

STANDARDIZATION OF NOMENCLATURE OF CHROMATICS AND COLORIMETRY.

A comprehensive, preliminary draft of a report on nomenclature and standards of colorimetry has been prepared and submitted to the Optical Society of America. This draft comprises about 50 typewritten pages and 6 tables, and has a table of contents as follows:

Introduction: Nomenclature, including General Terminology; Fundamental Psychologic Terms; Outline of the Methods of Practical Colorimetry; Classification of the Methods of Measurement Contributory to Colorimetry; Terms Relating to Transmission; the Physical Terms of Homo-hetero-analysis and Their Correlation with the Attributes of Color; Standards, including Standards of Spectral Energy Distribution; Transmission Standards, and Reflection Standards.

Bibliography: Usage of Terms Relating to the Attributes of Color and Their Correlatives in Stimulus; Usage of the word "Light."

TREATISE ON PYROMETRIC PRACTICE.

The Bureau has completed the manuscript of a comprehensive treatise on modern pyrometry under the title "Pyrometric Practice." The object of this treatise is to provide investigators, manufacturers, and others who may be concerned with the measurement of high temperatures with complete information as to the present state of the art of pyrometry, the instruments and methods used, the precautions that must be observed to obtain correct results, and to illustrate some of the industrial applications of pyromery. The scope of the paper is indicated from the following subheads: Temperature scale; high temperature therometry; thermal electrical pyrometry; optical pyrometry; radiation pyrometry; resistance thermometry; recording pyrometry; high temperature control; melting point methods at high temperatures; standardization of pyrometers and industrial applications of pyrometry. This paper will be ready in 6 to 9 months. The completed volume will consist of 300 pages and will contain a large number of illustrations. The number of copies available for free distribution will probably be small, but provision will be made by which it can be obtained at cost from the Superintendent of Documents.

SOME NEW EXPERIMENTS WITH THE LEUCOSCOPE AND ITS APPLICATION TO PYROMETRY.

THE leucoscope is an instrument developed and used by Helmholtz and his pupils between 1878 and 1888, primarily for the study of vision. Since that time practically no further work has been done with it. Recent experiments at the Bureau have shown the applicability of the instrument to pyrometry and new laws of the instrument have been discovered relating its readings to temperature and spectral energy distribution in a light source or furnace. These data were communicated to the Optical Society of America and will be published in the journal of that society.

USE OF "OVER-SANDED" MIXES OF CONCRETE.

IN commercial work it has been found that concrete foremen will decrease the ratio of sand to gravel so as to produce a better working concrete, namely, one with more fine material in it; and preliminary work has been started in the laboratory to determine the effect of "over-sanding" the time-honored 1:2:4 and 1:3:6 mixes in which the ratio of fine to coarse aggregate is 1 to 2. Very often with the very best of material these standard mixes, if actually used, will produce harsh, segregating, unworkable mixes. This is particularly true when crushed slag or crushed stone are used as coarse aggregate. One of the tests which has been carried out was in conjunction with a practical problem. A crushed limestone was submitted for test in 1:2:4 concrete with river sand as the fine aggregate. This mix was made but was found to be harsh and segregating. A 1:3:3 mix of the same materials was found to be much more workable when made so as to have the same consistency. Strengths were found to be higher for the over-sanded mix at an age of 28 days, and it was also found that contrary to the general belief less cement was used in the over-sanded mix. The following table shows the results numerically:

Mix	% Water	Cement Lb. per cu. yd.	Compressive strength Lb. per sq. in.
			28 days old
1:2:4	8.33	508	768
1:3:3	8.86	487	988

The consistency of the mix was wet and was the same for both mixes.

Further tests are under way and the following mixes in two consistencies have been made up: 1:2:4, 1:2-½:3-½, 1:3:3 and 1:3:6, 1:3-½:5-½, 1:4:5. Seven-day strength results show that all mixes of the same proportion of cement to aggregate have substantially the same strength and also that the mixes with the most sand use the least amount of cement per cubic yard.

Notes in Science in America

Abstracts of Current Literature

Prepared by Edward Gleason Spaulding, Professor of Philosophy, Princeton University

VARIABILITY OF SUN'S RADIATION.

MR. C. G. ABBOTT of the Smithsonian Astrophysical Observatory gives an account of the results of investigations on the variability of the sun's radiation in a paper published in the Proceedings of the National Academy of Sciences for February, 1920. It is found that the investigations of the Smithsonian Astrophysical Observatory conducted at Washington, Mt. Wilson, Mt. Whitney, Bassour (Algeria), and now the investigations supported by the Smithsonian Institution from its private funds in North Carolina and Chile have all united in giving the impression that the solar radiation is not constant, but varies from day to day through a range of certainly five and possibly at times ten per cent. The conclusion that the sun is a variable star is confirmed in several ways, but most notably by the results of measurements made by the Smithsonian Astrophysical Observatory at Mt. Wilson, California, on the distribution of energy along the diameter of the solar image. These measurements indicate, as was well known before, that the edge of the sun's disc is less bright than the center, and that the contrast of brightness between the center and the edge varies according to the wave-length of light, being greater for short wave-lengths, less for long.

But the measurements of recent years have shown that not only is there a variation of contrast by wave-length, but also a variation of contrast with the time. The contrast in each wave-length is different for different days of observation and, on the average, for different years of observation. The changes of contrast have been compared with the changes of total radiation of the sun determined by the aid of the pyrheliometer and spectrobolometer, and it is found that there is a moderate degree of correlation between them. The correlation is of two kinds. For variations of long periods of years, high values of the solar constant are found associated with high values of contrast between the center and edge of the sun. On the contrary, for the short period variations of the solar radiation, occupying a few days, weeks, or months, it is found that high values of the solar radiation are associated with diminished values of the solar contrast.

The cause of this two-fold variation is reasonably explained. When the sun grows hotter and thus increases its output of radiation along with increased solar activity, as indicated by sun spots, prominences, and other visible solar phenomena, this would tend to cause a greater degree of contrast. For since if the solar temperature were zero there would be zero contrast, the higher the temperature the higher the contrast. But the sun is probably entirely gaseous, and certainly its outer layers are so, and these may become more turbid at times, just as the earth's atmosphere becomes more hazy at some times than at others. Accompanying increased turbidity of the solar atmosphere there would be found a diminished value of the solar constant of radiation. But since the path of the solar ray is oblique in the solar atmosphere near the edge of the sun, the path is longer there and the effects of the turbidity would be greater at the edges rather than at the center. Thus with the increase of turbidity the contrast of brightness would increase accompanying a diminished value of the solar constant of radiation. In this way it appears that the two-fold variations of the sun which have been found may be reasonably explained.

EFFECT OF MAGNETIC FIELD ON ELECTRIC FURNACE SPECTRA.

DR. G. E. HALE of the Mount Wilson Observatory communicates to the National Academy of Sciences Proceedings, February, 1920, the results of a study, by Arthur S. King, of *the effect of a magnetic field on electric furnace spectra.*

Investigations on the splitting of spectrum lines by the magnetic field have employed, except in rare instances, the electric spark as the source of light. It has proved impracticable to maintain an arc between the poles of a magnet, though an apparatus giving a succession of flashes has been employed. The flame, because of its weak luminosity, has but

limited usefulness. The electric furnace, if its size does not prevent its use in the magnetic field, will evidently do work not at present take ncare of. While the furnace does not give the enhanced lines peculiar to the spark, the other lines shown by the arc and spark occur for the most part in the furnace spectrum. In addition, the furnace is found to show a large number of lines which are produced only with great difficulty by either the arc or the spark, and for which we have as yet no data as to their magnetic separation. A further advantage over the spark for the lines common to both is the extreme sharpness of furnace lines when the apparatus is enclosed in a vacuum chamber, a feature which should add materially to the definition of the Zeeman components.

Pending the construction of a more powerful apparatus, a simple tube furnace was arranged for use in a magnetic field. A graphite tube, 10 cm. long, was placed axially between the poles of a Weiss electro-magnet. The jacket enclosing the tube and the contact blocks at the ends were water-cooled. A field of 6,500 gauses separated the components of most lines sufficiently to permit measurements of fair accuracy and to show the characteristic features of the source. The spectra of iron and vanadium received the chief attention, and measurements were made for a considerable number of lines having well-defined components. A comparison of lines common to furnace and spark showed no difference either in the number and arrangement of components or in their separation in the two sources, the very different excitation in the two cases appearing to have no effect on the magnetic characteristics. The furnace and spark can thus be used to supplement each other in studying the magnetic behavior of all classes of lines. As was expected, separations were obtained for many characteristic furnace lines which the spark emits very faintly. An outstanding feature of these lines for the iron spectrum is a prevailing large separation and simple triplet structure. Lines of this class are often of special interest in the study of sun-spot spectra.

The furnace offers unique facilities for the production of the inverse Zeeman effect when a plug is placed in the tube. The absorption spectra resulting from this arrangement were discussed in the preceding communication. An extended study was made of the magnetic components given in absorption by this method. No difference was observed as to character or magnitude of separation as compared with the effects for the emission spectrum. A means of direct comparison with the magnetic effects for absorption lines in the solar spectrum is thus afforded, which may be expected to be very useful in tests as to polarization and other features at various angles to the lines of force.

CONTEMPORANEOUS EVOLUTION OF WARM-BLOODED ANIMALS AND OF FLOWERING PLANTS

In the American Journal of Science for March, Mr. Edward W. Berry directs attention to the practically contemporaneous evolution of warm-blooded animals and of fruit- and seed-bearing plants and to the improbability of the evolution of the former had the latter evolution not taken place.

The point is made that no one heretofore has suggested the correlation of these striking events, which in each case represent the climatic development of the respective kingdoms. As regards the known geological records the first mammals antedate the first birds and both antedate the flowering plants, and the last group furnish evidence of their late Mesozoic differentiation which the mammals do not, except as this is inferred from the sudden appearance of mammals in previously unknown variety in the early Eocene.

The actual ancestry of the flowering plants is still shrouded in the mists of ignorance. Historically their earliest appearance in the geological record is in later Lower Cretaceous time where they are represented by leaf remains and petrified wood. These earliest known types do not appear to be primitive, and the fact that they have been found in such widely separated regions as Europe, Greenland, North America, New Zealand and Australia justifies the assumption that they must have had an extended antecedent history running back well into the older Mesozoic, although they could not have become fully differentiated, abundant or varied in those earlier days.

A characteristic feature of the flowering plants, not shared by the members of any other plant phylum, is that the ovary is closed and that after fertilization it, together with various accessory parts, develops into a fruit or pericarp. The production of fruit, using that term in the technical rather than in the popular sense, is a characteristic feature of the flowering plants, and the mere fact that fruit is a vernacular as well as a scientific term lends emphasis to the point that Mr. Berry elaborates.

Plants, like all other organisms, are concerned chiefly with problems of nutrition and reproduction. The formation of seeds, an event which occurred during the Paleozoic, was an exceedingly great step in advance over the spore-forming habit of the earlier stocks—the present day dominance of the seed plants furnishing the proof of this statement, if proof be considered necessary. Fruit forming, which is of a different category from seed formation, is not only a protective device for the seeds with their concentrated food stuffs stored away for utilization by the germinating plantlet, but is also the great factor in distribution.

Turning to the geologic record of the warm-blooded animals, Mr. Berry notes that the oldest known bird, *Archaeopteryx*, partly reptilian in character, comes from the upper Jurassic and was a carnivorous type, as were also the toothed birds of the Cretaceous. There are no records of frugivorous birds, or in fact any modern birds until a time subsequent to the differentiation of numerous families of flowering plants.

The geologic record of the primitive mammals is exceedingly imperfect. The earliest known are recorded from the upper Triassic of Europe, North America (Keuper of North Carolina), and South Africa (Stormberg beds). Essentially similar Prototherian or Metatherian types are present in the Stonesfield slates and Purbeck beds of England, in the supposed Jurassic of South Africa, and in the Cretaceous of North America, and possibly Patagonia. They survived as the archaic mammals of the earliest known Eocene terrestrial faunas.

That the evolution of the higher plants was one of the important factors in the comparatively sudden efflorescence of the mammal and bird stocks, Mr. Berry maintains, cannot be doubted. The small Prototheria of the Triassic did not change greatly during the lapse of ages because the food supply did not change greatly and because of the competition for it of the reigning race of reptiles, and it may be suggested that the changing food supply, due to the evolution of the flowering plants and which is suggested as one of the important factors in the evolution of the higher mammals, was also one of the factors that spelled the doom of the overgrown and specialized Reptilia of the Mesozoic.

The earliest mammals appear to have been insectivorous. The various orders of insects are old geologically and that they existed comfortably before the higher plants were evolved is obvious, but that the latter became an attractive source of food and were the stimulus for very many new genera and species cannot be doubted. Thus indirectly the flowering plants greatly increased the food supply of the insectivorous mammals. The Rodentia, Edentata and Primates depend almost entirely upon the flowering plants for food, as do the Ungulata, and indirectly the Carnivora, since the latter group is chiefly dependent on the aforementioned groups and to a less extent upon birds or cold-blooded prey.

Upper Cretaceous floras furnish a large number of types of great food value, and among fruits—palm nuts, figs, walnuts, persimmons, etc. Very many fleshy fruits are found in the Eocene floras and these even include among their number such specialized fruits as dates and zapodillas (Eoachras). The Ptilodus skull described by Gidley (1909) from the Fort Union Eocene of Montana not only proved the marsupial character of that genus, but showed considerable dental speciali-

zation which his describer attributed to frugivorous habits.

The relatively sudden differentiation of flowering plants immediately antecedent to the equally sudden differentiation of the Eocene Mammalia was not fortuitous, but the two series of events are to be correlated. Both were largely accomplished during a time when the sea had retreated for the most part from the continents and land surfaces were much extended. This also was possibly an evolutionary factor in both kingdoms as were any climatic changes that may have taken place. It is clear that the long period of land emergence that intervened between the time of deposition of the latest Cretaceous and the earliest Eocene marine sediments in most regions was the theater of evolution of the modernized plants and animals of the Eocene record.

In conclusion Mr. Berry finds that it requires but little argument to prove that human civilization could scarcely have been attained but for the presence of the flowering plants. Although the pre-human and eohuman races were largely carnivorous and supplemented a diet of flesh, fish and fowl (including shellfish) by such fruits and seeds as nature furnished them, and although certain existing races, such as the Esquimaux, maintain themselves without agriculture, the civilization of history have all had their basis in an agricultural society, and all crop plants (except such unimportant foods as fungi, seaweed, etc.) of all races, ancient or modern, are angiosperms or flowering plants.

It is only by agriculture that large numbers in settled communities can be sustained and the flower of progress can bloom. Instances of the greatest production of concentrated energy are furnished by some of the grains, one-third of the total weight of the whole plant being represented by the concentrated foodstuffs of the seeds. Game, even as abundant and as stupid as was the bison of our western prairies, could not afford a basis for a civilization, and even in this instance it might be recalled that the basis of the abundance of the bison was the fodder furnished by members of the angiosperm alliance. Similarly the food of the camels, sheep, goats and horses of the nomadic races was this type of plant.

SECRET SIGNALLING BY LIGHT RAYS.

OF the numerous ingenious applications of scientific knowledge to the solutions of problems which were emphasized by the world war are the investigations of R. W. Wood on the sending and receiving of signals by means of light waves, both within and beyond the confines of the visible spectrum, merit attention. Ordinary parabolic mirrors are not suitable for sending signals over long distances, from the rear to the front, because the field covered by the cross-section of the inaccurate beam is so large as to incur the risk of including a portion of the enemy's trenches simultaneously with the proper receiving station. This prohibitive characteristic is entirely avoided in Wood's "flash telescope."

This apparatus consisted primarily of a telescope having a tungsten lamp at the common focus of the objective and ocular. The objective was a non-cemented doublet, of three-inch linear aperture, corrected to have the same focal length for the near infra-red and for a certain wave-length in the ultra-violet. The tungsten lamp was of the nitrogen-filled type containing a very short spiral filament. With the low power ocular employed, the total magnification produced by the telescope was about fourteen fold. The focussing was effected by moving the objective along its optic axis, the position of the lamp being invariable relatively to the telescope tube, etc. The filter wheel was placed between the lamp and the objective. By rotating this wheel so as to interpose the proper ray-filter in the path of the beam of light, it was possible to flash signals either with white or with infra-red, or with ultra-violet light. To use the telescope it was only necessary to point the tube in such a direction as to cause the image of the lamp filament to be accurately superposed upon the inverted image of the receiving station. As regards efficiency, the following comparative data may be mentioned. A parabolic reflecting lamp of 35 cm. aperture carries less than 10 km. The flash-telescope, when used in broad daylight, carries 30 km., while using less than one-half the power consumed by the search-light.

Some additional advantages of Wood's telescope are: (a) the beam of light is a very narrow cone (cross-section about 6 ft. at a distance of 1 mile) so that secrecy is assured; (b) the telescope can be aimed with great precision; (c) the instrument can be used as a receiver of signals sent out by a very distant station; and (d) ordinary displacements of the lamp with respect to the tube, arising from shocks incident upon transportation, have no deleterious influence on the accuracy of pointing. Case (d) does not hold true for parabolic reflecting lamps.

When conditions were such as to preclude the use of white signals in full daylight, the difficulty was overcome by employing radiations between L6900 and L7500. The ray filters were made, in the well-known way, by staining gelatin with appropriate aniline dyes. In general, the filter was compound, one gelatin sheet being stained with cyanin and the superposed plate with almost any deep orange coloring matter. The flash telescope was always provided with two infra-red screens, the brighter and darker filters being best suited for signalling over distances from two to six miles, and under two miles, respectively. By using spectacles or field glasses, etc., in conjunction with color screens of the same kind as in the sending apparatus, the dazzling daylight was decreased in intensity to a very much greater degree than the infra-red radiations, thus causing the distant signal lamp to assume the appearance of a brilliant star and approximately black landscape.

Secret signalling at night was accomplished by using ultra-violet rays. The filters consisted of circular disks of black glass having an oxide of nickel as the coloring base. The receiving apparatus was essentially a short focus telescope, of very wide aperture, provided with a screen coated with barium platino-cyanide and coinciding with a focal plane of the condensing objective. This screen was viewed through a small ocular. The ultra-violet light was not transmitted by the screen, of course, but the focal spot was made visible by the bright green phosphorescence of the barium compound. With the less dense filter signals where received at a distance of 5.5 miles, and with the deeper filters at 2.5 miles.

To establish large beacons or reference points for naval and aeronautical purposes the best results were obtained by using a quartz mercury arc covered with a screen of nickel glass. The small amount of red light which would be transmitted by this kind of glass is not emitted by the mercury arc so that, beyond very short distances, the screened lamp is not visible to the unaided eye. On the other hand, the powerful mercury line at $\lambda 3650$ falls exactly at the center of the transmission band of nickel glass. By employing an appropriate phosphorescent detecting apparatus, a lamp arranged in the manner just suggested has been seen by an observer in an airplane flying at an elevation of 3,000 meters.

In addition to the practical application of the ultra-violet lamp, the original paper contains an interesting account of certain striking phenomena which occur when various objects are illuminated with ultra-violet light of practically a single wave-length. For example, the lens of the human eye becomes phosphorescent. The skin assumes a peculiar hue, natural teeth phosphoresce brilliantly, false teeth appear black, etc. By using a very dilute solution of potassium chromate, the author has taken photographs (reproduced in the paper) of his face and of one hand. This filter transmits the radiations that excite the phosphorescent screen, but it completely absorbs the ultra-violet rays reflected and scattered by the skin. Old cicatrices, ordinarily invisible, come out with great distinctness. In this connection, the author suggests the possibility of taking advantage of these phenomena in physiological researches.—From *American Journal of Science*, March, 1920.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

By H. E. Howe, Member of American Chemical Society

FOOD ECONOMY.

Frequently in discussing the competition which the Oriental laborer gives the American workman we hear mention made of the fact that a small amount of inexpensive food seems to satisfy the man from the Far East; whereas, the American must have his meat and a fairly complete assortment of vegetables. The principal food of many thousands in the Far East is made up of rice and some product of the soy bean, with now and then a small portion of fish.

In studying the characteristics of the various varieties of bean it would appear that through investigation under the direction of Dr. C. O. Johns of the Bureau of Chemistry, Department of Agriculture, the scientific basis for the efficiency of the Oriental diet may have been discovered. One of the essential ingredients in the diet of man is protein. Recent researches have proven with experiments upon animals that it is not only important to have a sufficient quantity of protein, but it is essential, if body growth is to be promoted, to have particular kinds of protein. Many of the proteins will sustain the body, but they do not all yield the amino acids necessary for growth upon their being broken up by the digestive processes. The proteins are valuable because of these amino acids, and cystine seems to be the amino acid which exerts the greatest influence upon growth. It has been found that the beans most generally cultivated in our country do not yield this important amino acid and consequently will not promote growth. The Navy bean will maintain the body and will assist in the rebuilding of fatigued organs, but if children derived no protein from other sources than the Navy of lima beans their growth would be practically stationary. On the other hand, the soy bean, which is of Chinese origin, and the mung bean do yield this valuable acid, and being high in nitrogenous material the soy bean may almost be considered a complete ration. The mung bean is a leading ingredient in chop suey and is largely used by the Chinese in producing sprouts which are an ingredient in much of their food and which are rich in vitamines.

If the press cake from the soy bean oil presses is used with peanut flour and white flour to make a loaf of bread it is claimed that such a loaf is a complete ration and will be found more easily assimilated than meat and equally nutritious and sustaining. Moreover, the soy bean cake has a neutral flavor so that in it we have the possibility of an important food base without carbohydrates with which a great variety of attractive, nutritious dishes could be prepared, depending upon other materials to impart the desired flavor, form, and texture.

Of late an increasing acreage has been devoted to raising soy beans, particularly in the South where the boll weevil makes the cultivation of diversified crops a necessity. But we have not yet learned the use of the soy bean and its products in our American foods. The soy bean cake has been used as a fertilizer because of the high protein it contains, and more recently as a stock food for the same reason. It certainly would seem more economical to make this protein an article for direct human consumption, rather than take the roundabout way through the animal.

The variety of materials made from the soy bean and its products in the Orient is remarkable. It forms the basis for an artificial milk. It is fermented into a drink. It affords an artificial cheese and the casein recovered from it has a variety of application. It will be seen, therefore, that nature has been particularly good to the Orient and naturally provided it with a particularly useful variety of bean. Without knowing why, the Oriental has found that the bean is a satisfactory item in his diet and it appears that he has chosen his food upon a scientific basis. It remains to be seen whether Americans will be willing to act upon the information that has come to light, and in time make the soy bean as prominent an article in our commissary as the Navy bean now is.

A NEW TYPE OF CATALYST.

Mr. Benjamin W. Elder has secured patents covering a new type of catalyst which is suitable for hydrogenation. It is prepared by subjecting nickel to the action of silica, pumice, carborundum, diatomaceous earth or other very finely divided abrasive, and this action may take place either dry or in the presence of oil. The preparation made under oil is found to be more active. In the laboratory it has been found that if a plate of nickel be rubbed over another plate with oil and an abrasive between them catalytic nickel may be produced. On a commercial scale a porcelain lined pebble mill may be used in which nickel shot, the abrasive, and some oil, such as cotton seed oil, are placed. The action of the mill produces finely divided catalytic nickel suspended in the oil. There seems to be a direct relation between the activity of the catalyst, the fineness of the abrasive used, and the length of time the grinding is carried on.

The process appears to have considerable practical importance and at the same time seems to make it necessary to discard some of our former theories of catlysts. Thus the catalyst prepared by Mr. Elder's process is metallic, indicating that a sub-oxide nickel catalyst is not essential for hydrogenation. Also the theory that high temperatures if used in the preparation of metals for catalysts would render them unsuited must be revised, since the nickel shot used in the pebble mill has been heated above the melting point of nickel. Where nickel oxide is reduced to provide very finely divided nickel it has been demonstrated that low temperatures produce active and high temperatures inactive catalysts. This apparently does not hold where the metal itself is concerned.

HYDROCYANIC ACID GAS IN FUMIGATION.

Much has been written concerning the use of this deadly poison in fumigation, for there are many forms of pests which apparently cannot be entirely exterminated by any other means. This is true for instance with regard to the type of insect which sometimes infests libraries, there to feed upon the material found in the covers of books and the materials used in binding them. There is also no other way so sure to exterminate the moth, whose work may soon be regarded a mark of distinction since he prefers wool for his diet. In an effort to keep from our shores the pests of the cotton crop which infest the Egyptian cotton fields, all cotton imported from that part of the world is given a hydrocyanic acid gas treatment in a special apparatus designed to admit whole bales.

Unfortunately, so far as its application is concerned, the hydrocyanic acid gas is so poisonous that it cannot be used with the same freedom as we use other insecticides. Thus, if a house is to be fumigated with it great care must be exercised in effectively sealing doors, windows, and other openings, and the gas generators started in the attic so that the operators may rapidly work their way down and out of the house. Many hours must also elapse before the house can be entered again.

In the April issue of the Popular Science Monthly, a further use of hydrocyanic acid gas is described. It is proposed

to isolate diseased trees and those with pests not disturbed by other types of insecticides, by dropping a tent over them from a captive balloon.

Tanks of hydrocyanic acid gas can be brought to the location and the gas released beneath the tent with safety. After a fixed period of time, the captive balloon is brought back to lift the tent off and carry it away for a repetition of the performance.

BORAX IN FERTILIZERS.

The following note is from a recent issue of Chemical and Metallurgical Engineering:

Two pounds per acre of anhydrous borax marks the limit of safety with which it may be used in fertilizer when the fertilizer is put in the row so that seeds or plants are brought into virtual contact with it. This is the opinion of the specialists of the Department of Agriculture who have been studying the matter of borax in fertilizer. As a result the Department has advised all fertilizer manufacturers and dealers in fertilizer that more than two pounds of borax per ton of mixed fertilizers will not be allowed unless the presence of an excess of that amount is indicated plainly on the container.

When fertilizer is broadcasted and thoroughly mixed with the soil, the Department's specialists agree, ten pounds of borax may be contained in the fertilizer used on an acre of ground without danger to the crops. The Department describes the experience of farmers in some sections of the country as disastrous as a result of using fertilizer containing borax. It is to guard against a similar experience that the Department on December 9 put into effect its drastic regulations regarding the borax content of fertilizer.

Borax is described as being "highly toxic to crop plants," and was contained in the potash derived from at least one of the new sources which were resorted to after the war had cut off foreign supplies of potash. The Department also has ascertained that nitrate of soda as imported also contained some borax. The Department is also authority for the statement that borax was "not known to have been present in appreciable quantities in the materials commercially available for fertilizer uses prior to the war."

Recent research on potash materials from the source to which reference is made in the above is reported as successful in eliminating the borax so that it will be possible to supply material to specification. In view of this progress, it is to be regretted that the experience of last year will make it difficult to overcome the prejudice against his material, which has quite naturally resulted.

SCIENTIFIC CONTROL.

Whatever the attitude toward research may be in a given industry, it is usually not difficult to establish the desirability for scientific control which if it has any chance at all is pretty sure to be the entering wedge for research. There is a case of a concern which began with a two-man laboratory and today the Department of Research and Development occupies the entire building which was then the large new factory.

The investigation which goes with scientific control frequently uncovers valuable bits of information in unsuspected places. Working upon the measurement of the fiber spun in a cotton mill, an investigator found that whereas the mill purchased fiber which averaged an inch and a quarter in length by accurate measurement, it spun fibers averaging one and one-eighth inches. These measurements were made by means of a projection apparatus which threw the picture of the fiber upon a screen where it could be quickly measured with a reasonable degree of accuracy, so it did not depend upon the estimate of some one experienced in pulling the cotton to determine the length of staple. Further investigation proved that due to the way in which a part of the machinery had been set the fiber was actually being reduced in length as it went through the mill operations. Since the longer fibers bring a price above the base price fixed for shorter staple, it was obviously a large economical loss to purchase a longer fiber than was made and especially to purchase a long fiber only to shorten it in the machine operations. The textile industry is beginning to find that it has problems which may be solved by the application of science. A few of the mills have their own laboratories, but being unlike those industries founded upon a science this practice is not yet universal.

There is a very attractive research field in the utilization of a shorter staple. Of course a considerable quantity of this cotton is used now, but it seems probable that if we knew more about what takes place when the fiber is subjected to the various mechanical and chemical processes through which it passes that we could find ways of using the shorter fibers for some products for which at present the longer staple is considered an absolute necessity.

The clay working industries are among the most ancient of our civilization and the nature of the raw material makes it difficult to standardize and understand. The scientists have been at work, however, and those men who have been responsible for much of the progress are now calling to their assistance trained scientists for research and plant control.

The beauty of the work seems to be that the control laboratory soon finds the need of methods, data, and principles which have not been standardized or proven, and if in the right hands it begins sooner or later upon some small piece of research, which is pretty sure to be but the beginning of a large and ever widening program. There is danger, however, that control may be mistaken for research, but once convinced of the fact that science is the good investment claimed the far-sighted manufacturers prepare to go through with a well considered, broad plan of scientific work.

COAL TAR PRODUCTS IN THE RUBBER INDUSTRY.

In the Color Trade Journal for April, Dr. Frederick Dannereth dicusses the coal tar products used in the rubber industry and adds thereby still another reason for the passage of legislation now before Congress to encourage the establishment of an organic chemical and coal tar products industry in the United States. It should be emphasized again that a by-product of the dye industry is research in organic chemistry which is pretty certain not to be carried out otherwise. Further, it produces men with just the experience necessary for the conduct of a variety of organic chemical industries.

The article states that the coal tar products used in the rubber industry include the following: vat dyes for coloring rubber compounds; insoluble azo colors formed directly in the rubber; volatile liquids used in preparing rubber cements and as solvents in vulcanization by the cold cure; pitch products used as porosity corrective. Naphthol and amino phenol used as coagulents for latex, amino benzene derivatives are the accelerators of vulcanization and amino derivatives are used as the devulcanizing agents for waste rubber. Then we have cresols in reclaiming waste rubber goods, coal tar used in softening reclaimed waste rubber, and lamp black used as a filler and a pigment.

The accelerators of vulcanization have been the subject of much study of late and it is now practically agreed that the amino derivatives so used function generally as catalysts, which assist in carrying the sulphur to the rubber molecule. The use of an accelerator means that rubber mixtures may be vulcanized in 30 minutes, instead of two hours as formerly; so that three or four times as many tires may now be vulcanized with the same equipment. A better appreciation of what this means may be derived from the fact that there are tire factories producing from 15,000 to 20,000 tires per day. There has been some danger to the health of workers in the use of these organic accelerators, but this is said to be due largely to the older types of mixing machines now being gradually replaced by modern devices, in which the rubber, fillers, sulphur, and the accelerators are placed in the kneader and the machine closed and kept closed until a homogeneous compound has been obtained.

Dr. Dannereth, in discussing cements, points out that it is incorrect to refer to such materials as carbon bisulphide, carbon tetrachloride, petroleum, naphtha, etc., as solvents for rubber compounds for actually something less than one per cent of the rubber goes into solution. It is more proper to refer to these liquids as thinners. The manufacture of rubber cements consists in grinding the raw rubber or the rubber compound into a paste with the thinner, remembering that the mixture is highly inflammable. With such mixtures thin films of rubber may be obtained, and to enable the operator to work rapidly it is an advantage to use thinners having a high rate of evaporation.

The devulcanization of rubber compounds and the recovery of the used rubber contained in them is constantly becoming a more important field. Experiments have indicated that more than half the combined sulphur may be removed from a rubber compound and more lately a patent for a process of devulcanizing covers the absorption of the sulphur with some reagent, such as sodium, as rapidly as it is liberated by an amino substance.

THE ISOLATION OF VANADIUM.

How many motorists give any thought to the work which is done by scientists in many parts of the world that they may have their convenience and pleasure? Vanadium in the form of ferro-vanadium has literally made some of the lower priced automobiles possible and has also contributed directly to the production of more imposing cars since ferro-vanadium may be used in high speed tool steels, in the larger locomotives, and in special types of rails. Ferro-vanadium offers strength and durability with light weight, and being readily machinable requires but half the expense to produce an automobile part compared with its production from high carbon steel.

However, vanadium may be considered isolated since the only known large concentrated deposit of pure ore is to be found in the Peruvian Andes, nearly 17,000 feet above sea level. To date the ore has been brought out in 125 pound bags on the backs of llamas. The mine in question has constituted the commercial enterprise conducted at the highest altitude in the world. There have been a number of factors which have made it difficult to increase the output of ore to keep pace with the present demands for vanadium.

Americans are now building a railroad to this deposit and this feat involves overcoming extraordinary engineering difficulties. With the completion of this line the output of the mine will be greatly increased and eventually it is thought the price of vanadium may be lowered in consequence, although even now the price is but a fraction of that obtained for it when vanadium was discovered nearly 30 years ago.

GAS AS A FERTILIZER.

IN studying the elements which control the growth and production of plants at a time when it was difficult to secure sufficient fertilizer of different types, German chemists, working under pressure to produce the maximum quantity of food possible, turned their attention to the air. We know that plants breathe just as animals do and that carbon dioxide ordinarily present to the extent of 3-100 of one per cent in the air is essential to plant maintenance. Reasoning that since plants do so well on but three parts in 10,000 of carbon dioxide, and they might do better in the presence of a greater quantity, it was decided to try the experiment, using the carbon dioxide, which is a by-product in the production of pig iron.

During the production of 1,000 tons of pig iron 1,000 tons of coke are consumed, and 4,000 tons of carbon dioxide gas are turned into the air. If all of this carbon dioxide could be used, calculations indicate that about 4,000 tons of vegetable matter would be produced, and if even a small percentage of the gas were utilized the results might very well justify the cost incident to the distribution of the gas.

In Germany the experiments were begun in hot-houses and in a few days results were noticeable. Those plants receiving a higher percentage of carbon dioxide grew more luxuriantly, bloomed earlier, matured more rapidly, and gave an increase in yield. Thus, tomatoes increased 175 per cent in their yield and cucumbers 70 per cent, as compared with those grown at the same time under normal conditions. In order to extend the experiments to outdoor plots, perforated pipes were laid so that the gas could escape slowly in the vicinity of the plants, and, although much of the gas would of course escape, yields were obtained that could only be explained by the fact that the gas was used. Two bushels of barley grew where but one had grown before. Potatoes increased 150 per cent in yield and spinach did even better. producing 154 per cent of the crop grown on controlled plots under normal conditions.

It is reported that in 1918 seven acres were equipped with pipes to distribute the carbon dioxide and that on this larger area the substantial gains reported above were maintained or even increased. In one case, a crop that showed an increase of 18 per cent by the use of ordinary commercial fertilizer increased 82 per cent when both soil and air were fertilized. Of course gaseous fertilizers alone could be of but little consequence, for the plant must have the mineral salts, the nitrogen, and ammonia, which we know to be necessities for a good crop. It will be interesting to consider the possibilities in centers adjacent to manufacturing establishments where carbon dioxide is a by-product, and in those vicinities an increase is usually a vital thing. It is to be hoped that similar experiments at least to check the claims made by foreign investigators may be undertaken in our own country.

RAILROAD HELIUM REPURIFICATION PLANT.

As the cost of production of helium is high, a repurification plant has been designed to be carried by two standard 70-ton railroad cars, and to operate continuously with a capacity of from 1,000 to 2,000 cu. ft. per hour.

The plant is described in the *Aircraft Journal*, Jan. 24, 1920.

The power plant, a 120 hp. heavy duty gasoline engine connected to a direct-current generator, together with fuel and sleeping quarters for the crew, is situated in one car. The other car contains all the repurifying apparatus, consisting of electrically operated air and gas compressors, purifying column, manifolds, charging and discharging desiccators, cooling tower, water supply tanks, gasometer, testing apparatus, etc. The operation of repurification consists of the reduction of temperature and pressure of the impure helium until the impurity (air) is liquefied and drawn off, allowing the pure helium to escape as gas.

CHEMISTRY IN PLANT DISTRIBUTION.

MR. E. T. WHERRY in recent addresses has indicated something of the narrow limits in which science must work to be of the greatest use in special cases. As early as 300 B. C. observations were made that plants seemed to bear certain relations to different ores or soil compositions and the names of certain species may be traced to the preference which such plants seem to have for certain of the metallic elements. Of late some of the botanists reached the conclusion that the chemical nature of soil has no influence upon plant distribution and this undoubtedly has seemed to be true in the light of our data based upon older methods of analysis which did not permit determining the very small differences in soil acidity, which may now be discovered by means of a new series of very sensitive indicators.

These indicators were first studied in connection with bacteriological requirements, where the degree of acidity in the media is a very important factor. A series of dyes has been selected such that the hydrogen concentration can almost be found quantitatively by the color with this range of indicators, which behave differently as the concentration of ions increases

or diminishes. The preference of certain plants, such as the heath family, for soil largely composed of decayed wood has been traced to the increased acidity of such soils. Mr. Wherry related one example where growth about a rotted log tended to confine the soil so that it was three times as acid as water which flowed adjacent to it.

It has also been demonstrated that methyl red has the right range of color changes to indicate whether or not a given soil is sufficiently acid to grow scab-free potatoes. By taking a small sample of a selected soil, shaking it with water, and allowing the mixture to settle, the supernatant fluid may be decanted and a few drops of the prepared indicator added. If the color of the fluid is then orange or yellow it is a clear indication that the soil is not sufficiently acid, but if it be red or violet red, potatoes may be planted in it with the assurance that they will be scab-free. It is possible to conduct all of such tests in the field using distilled water, of which but a small quantity is necessary, and the indicators, a set of which may be silpped into the pocket.

The study of acidity and alkalinity of soils with these new indicators is still under way and it will be seen at once that there is a direct relation between this work and maximum plant production. Of course it will be some time before it becomes the practice of those who now do their planting according to the phase of the moon to resort to test tubes and hydrogen ion indicators to guide them in their agriculture, but all work of this kind assists us in understanding more of nature's ways and perhaps ultimately in formulating national food production plans.

AMERICAN CHEMICAL SOCIETY.

The spring meeting of the American Chemical Society has just been held in St. Louis with an unusually large attendance of men from all over this country and abroad. The Society has become the largest scientific society in the world devoted to a single branch of science, its membership now being approximately 15,000. As usual, a number of interesting papers were presented in the eleven divisions and sections of the Society, some of which included more than fifty papers in their program. New sections are those devoted to leather chemistry and to sugar. There is a possibility in the near future that a section devoted to cellulose chemistry may be formed.

One subject which engages the attention of the chemical profession today is the supply of properly trained men, which depends upon maintaining in our professorial chairs and in all teaching positions men and women who are really qualified to teach chemistry and the allied subjects. It is becoming increasingly difficult for our educational institutions to maintain an adequate staff of teachers. Men are constantly leaving the classroom for the industrial laboratory, and the question of our future supply of chemists is becoming more and more a serious one. One method suggested at the meeting involves securing funds from which various payments can be made for the published researches of outstanding quality; these payments to be of a size making it a prize well worth the effort, offering an opportunity for the research men in the educational institutions to make substantial additions to their present income. The practicability of the proposed scheme is now under the consideration of the Committee appointed for the purpose.

A discussion of the present economic status of the chemist brought to light data which should be encouraging to the young men about to enter the profession. While the statistics available were gathered from only a few hundred reasearch men, they show that the chemist today is undoubtedly earning on the average as high a wage as does the average of those found in the other learned professions while a few competent chemists are required to go through the sort of "starvation stage," which in the past has been the doorway to a career in some of the other professions.

Many of the papers in the different fields of chemistry will appear in the publications of the American Chemical Society, notably the *Journal of Industrial Engineering Chemistry*.

THE COW AS A LABORATORY.

Until recently it would have been difficult to interest the stockmen in a study which had for its purpose determining whether it is better to feed an animal to be killed for beef or one which converts its food into milk, rather than into its own body tissue. There are perhaps several reasons for this, one being the difficulty experienced in some quarters in marketing large quantities of milk to advantage, but with the change in conditions which has emphasized the importance of condensed, evaporated, and dry milk it is conceivable that the question of whether it shall be animals for beef or a dairy that is to be supported may confront many a raiser of stock.

Dr. H. P. Armsby, an expert in animal nutrition, estimates that the energy of grain used in feeding the animal is recovered to about 18 per cent in milk for human consumption, but only about three and a half per cent of this energy reaches us in beef. An English official report states that the production of 100 calories of human food in the form of milk from a good cow requires that the animal be fed the equivalent of 2.9 pounds of starch. If a poor cow is maintained, the equivalent of 4.7 pounds of starch must be fed to secure the 100 calories in the form of milk; but if 100 calories in the form of beef is obtained from a two and a half year old steer, it has been found that the equivalent of 9 pounds of starch have been required to produce it. This would mean that a good milk cow returns 20 per cent of the energy value of that which she consumes, the poor milk cow 12 per cent, and a good beef steer but 6 per cent. Thus a poor milk cow is twice as efficient as a good beef steer, while the good milk cow is more than three times as efficient as a converter of energy from the form unsuited to human uses to that which is available for human food.

Professor Wood, a leading English agricultural expert, has determined that during the whole life of an animal, a cow returns one-twelfth as much food as she has consumed; this return being in the form of milk, veal, and beef. The beef animal returns but one-sixty-fourth, or but one-fifth as much during its whole life as does the cow.

It is apparent from this that when the price for animal feed-stuffs soar we should give more consideration to the efficiency of the laboratory to which we will take this raw material to be converted into human food. It also has a bearing upon the length of time the stockman can afford to fatten his animals for the market.

These considerations are based on protein fat and carbohydrate, but when we consider vitamines and mineral elements the cow has an added advantage. When beef animals are fed upon hydrocarbons and the usual parts of grains which furnish vitamines these are stored in the animal's tissues to but a slight extent, but they pass on in abundance to the milk so that coarse foods and grains not suitable for human food are converted into a form which makes it readily available in milk, though not in beef. Meat is also poor in calcium, which is comparatively abundant in milk.

These facts would seem to support the contention that a greater use of dairy products, rather than an increase in the consumption of meat, would become an economical procedure both for American agriculture and for the American consuming public. However, we need to know more concerning the problem of animal nutrition and its relation to the production of human food, considering the animal as a laboratory or plant in which the conversion from the inedible to the edible from the human standpoint can be accomplished. There are, however, a number of substances suitable for human consumption which find their way into stock feeds, and the proper use of these materials requires a long time study. The Committee on Food and Nutrition of the National Research Council is inviting support for this important program of investigation.

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

By A. Slobod

SELF-BAKING ELECTRODES.

A DECIDEDLY novel development was introduced in a paper by Prof. Joseph W. Richards, Lehigh University, on the Södeberg self-baking, continuous electrode. C. W. Södeberg, Christiania, Norway, imagined over ten years ago a self-baking electrode formed continuously from soft carbon mixture, which would be baked in the same furnace in which it is used and thus provide a continuous electrode. The first electrode of this kind was built by Mr. Södeberg in 1909. He naturally met with many difficulties in developing his idea and it was not until 1915 that he actively pushed the development in connection with the company with which he is now engineer. After considerable development work the company succeeded in overcoming in a practical manner all of the difficulties, and in November, 1918, a 400-mm. (16-in.) electrode was operated on a ferromanganese furnace without disturbances to the furnace and with no fracturing of the electrode. Since that time electrodes of all sizes up to 850 mm. (34-in.) diameter have been successfully operated, both in open and closed furnaces, in making ferrosilicon, silicomanganese and ferromolybdenum.

Dr. Richards said he saw last summer a 34-in. electrode of this type operating in a ferrosilicon furnace in Norway, the inventor of the electrode being his personal friend. The electrode is consumed very slowly and takes about a week to bake one meter. Several European firms are soon to make use of this type of electrode.

In the United States the new device is about to be tried out at the Anniston Steel Co., Anniston, Ala., on three furnaces, and a representative, Mr. Wesley, of the Norwegian interests, is now in this country overseeing the trial. There are to be at Anniston three 32-in. self-baking electrodes on ferrosilicon furnaces, and they are expected to be in operation soon. It is stated that any one desiring to see them will have the privilege.

During the discussion that followed Dr. Colin G. Fink of New York called attention to some advantages not presented by the author when he said that the new type evidently does away with the transportation problem and the spalling of modern electrodes if not stored properly. L. E. Saunders, Alundum Co., Niagara Falls, asked for information regarding the smoke from the baking of these electrodes and what could be done in case the iron casing used should contaminate the product. To this Dr. Richards replied that the baking is so slow there is virtually no smoke. What there is seems to be forced down into the interior of the electrode where carbon is perhaps deposited as the smoke comes in contact with the red hot carbon. If applied only to ferroalloys, contamination from the iron casing is out of the question, even in making calcium carbide it is claimed that the casing introduces no more than 0.20 per cent of iron into the product. Where aluminum is to be refined or melted, an aluminum casing might be used.—Meeting of the American Electrochemical Society at Boston, April 10, 1920. *Iron Age*, April 15, 1920.

TIDAL POWER.

OWING to the scarcity and high cost of coal, tidal power developments now come within the range of commercial possibility. In the *Electrical Times* of December 11, 1919, a proposed tidal development at Hopewell (England) is described. The data given for this scheme provides a basis for consideration of an entirely different method of development which is described below:

Broadly speaking, this system consists in dividing a tidal estuary into two or more basins by means of dams, in which turbines and generators are installed; sluice gates control the water, and the turbines are operated during the ebb and flow of the tides. During the flow the tide is allowed to rise outside the reservoirs until an adequate head to drive the turbines is reached, when it is passed through them, filling the reservoirs, until it turns and starts to fall. The sluice gates are then shut until the ebbing tide has fallen sufficiently below the level of the water now impounded in the reservoirs to produce the requisite head again to drive the turbines, through which the impounded water is then drained off until the tide again turns and starts to rise. During the period that elapses before the requisite head is reached to drive the turbines, after the turn of the high and low tide, power is produced by water filling into or draining from a subsidiary reservoir or reservoirs.

On the basis of the above system several schemes are presented diagrammatically by the author. Under scheme No. 1, for instance, the turbines operate through four cycles produced by means of a main reservoir marked A and a subsidiary reservoir marked B. Times are reckoned from low tide, which is considered as "zero" hour. The operation of the plant should now be traced through the four cycles.

Cycle 1. Main turbines run from 2 to 6½ hours by tidal water filling reservoir A direct.

Cycle 2. From 6½ to 8¼ hours subsidiary turbines take the load, being operated by water filling reservoir B from reservoir A, while the tide outside is falling.

Cycle 3. From 8¼ to 0¼ hours the main turbines are once more run by the water impounded in reservoir A, draining back to the sea simultaneously with the dropping of the tide.

Cycle 4. From 0¼ to 2 hours the auxiliary turbines again take the load, being operated by water in reservoir B draining back to reservoir A, which is then practically empty, while the tide outside is rising sufficiently to produce the requisite head for a fresh series of cycles to commence.

A power development such as that at Hopewell could be started on the lines indicated in the above scheme by providing dams and sluices sufficient to control water levels up to the full capacity of reservoirs A and B and by installing turbines and generators sufficient only to meet first requirements. The production of 700,000 horse-power is possible at Hopewell.—A. Struben, *Electrical Times*, London, February 26, 1920. Vol. 57, pp. 171-73.

CARBON ARCS FOR SEARCHLIGHTS.

AT the request of the British Admiralty a series of experiments were undertaken with the object: (1) of developing the best method of testing carbons in order to prove their value for searchlights; (2) of comparing the relative qualities of existing carbons, other than flame carbons, for producing high-intensity searchlight beams; (3) of determining what improvement can be made either in the carbons themselves or in the methods of burning them.

It was at first proposed to make measurements of illumination at different parts of a searchlight beam under actual working conditions in the open, but the sources of errors encountered were so great as to cause this method to be abandoned in favor of an indoor method of test, at any rate for the first series of experiments. The laboratory equipment consisted of an integrating photometer of cubical form fully described in the paper, and simultaneous measurements were made of the total flux of light emitted by the carbons alone and of the intrinsic brightness of the positive crater.

By this method a comparison was made of 13 different types of carbons, both those already in use in the British and French services, and others specially prepared by the General Electric Company. Experiments were made with two devices having for their object the control of the arc and its maintenance in a central part of the crater to ensure even burning of the carbons. One of these was an electromagnetic device, while the other depended upon a slow rotation of the positive carbon. For high current densities (0.3 amperes per sq. mm. and over) it was necessary to copper both positive and negative carbons. It was found that while change of potential difference on the arc produced no definite detectable change of candle-power, an increase in arc length beyond a certain value produced a decrease both of crater brilliancy and of candle-power. It seems likely that if allowance is made for the light obscured by the negative carbon, the shortening of the arc will be found to produce an increased average candle-power even at short arc lengths, but the exact amount of the obscuration is difficult to determine with accuracy.

In general it seems to be clearly established that for any one carbon the candle-power increases linearly with the current, while the crater brightness also shows a real increase, though its magnitude is not sufficient to determine the form of the relationship in this case. For the types of carbons considered, and apart from smoothness of running, there seems to be no definite difference of any magnitude either on average candle-power or crater brightness for carbons of the same diameter run at the same current. The efficiency in candle-power per ampere increases, however, for the same current density as the diameter of the positive carbon increased.—C. C. Paterson and others. Journal of the Institution of Electrical Engineers, January, 1920. Vol. 58, pp. 88-97. Discussion, pp. 97-106.

NEW PRIMARY BATTERY—AN AIR DEPOLARIZER.

M. Féry, Professor of the Municipal School of Physics and Industrial Chemistry of the city of Paris, designed a cell of interest in view of the novel method of dispensing with the use of the dioxide of manganese depolarizer in the Leclanché type of primary cell. The positive electrode of the new cell is a vertical cylinder of carbon of a somewhat porous nature. The negative electrode consists of a zinc plate placed horizontally at the bottom of the cell, and the exciting liquid is a solution of sal ammoniac. The porous carbon plays the rôle of a catalytic agent between the oxygen of the air and the hydrogen issuing from the electrolyte. The atmosphere is, therefore, utilized as a depolarizing agent in the action of the battery. This depolarizing operation is facilitated by the remoteness of the zinc plate from the top of the cell, at which point the air contact occurs. Zinc being a metal very easily oxidizable would tend to combine with oxygen, and it would therefore be detrimental, both to the constancy of the battery and to the zinc plate, were the latter not placed at the bottom of the cell.

Arrangements were made by the French technical authorities to put the Féry cell under trial on telegraph and telephone circuits. In the latter case the cells were used as a local battery. The telegraph offices at St. Cyr were equipped with the Féry cell in September, 1918, since which date the batteries have rigorously remained constant. At St. Cyr, after 250 days of service, each of the zinc plates had only lost 8 grm. weight. The constancy of the Féry cell is an extremely important feature—a quality which is not obtainable with the use of the ordinary Leclanché battery.

The Féry cell costs less than a cell in which dioxide of manganese is used, and when the zinc has been absorbed by the chemical action a new zinc plate and a renewal of the sal ammoniac are all that need be provided in order to obtain the equivalent of a new cell. Both as regards prime costs and annual maintenance charges, therefore, the new cell is less expensive than the manganese sac type of Leclanché battery. The French authorities have been impressed with the results of these experiments and have expressed the opinion that the cell should be employed in both the telegraph and the telephone services.—Annales des Postes, Télégraphes et Téléphones.—Journal of the Post Office Electrical Engineers, April, 1920.

EARTHING.

A sub-committee of the Institution of Electrical Engineers was asked to consider the whole question of earthing, including the time element of circuit breakers, the heating of conductors, the current-carrying capacity of the apparatus earthed, the drop of pressure in metal sheating and the number of earth wires required. In accordance with these instructions the sub-committee had performed considerable experimental work and recently brought in its report making the following recommendations:

1. Earthing conductors must be of the numbers and sizes set forth in the tables attached to the rules for each size of working conductor.

2. They should be of high conductivity copper, tinned or otherwise protected against corrosion, and protected against mechanical injury.

3. The smallest allowable size of earthing conductor should be 1/14 S.W.G., and the largest individual conductor should be 19/17 S.W.G., and that all conductors larger than 1/14 S.W.G. should be stranded.

4. When a larger section of earthing conductor than 19/17 S.W.G. is necessary, separate conductors must be used, and if earth plates or cylinders are employed, separate ones for each conductor must also be used.

5. Buried earth plates or cylinders must have an earth contact of not less than 4 sq. ft., and be surrounded on all sides by not less than 12 in. depth of finely broken coke. They should preferably be of cast iron or other durable metal, and the place selected for burying them must be permanently wet or, at least, damp.

6. Wherever an earth wire is connected to a pipe, or conduit, or cable sheath, or armoring, a substantially designed clip must be used. Sweating sockets also must be used at each end of the earth conductor for all sizes larger than 1/14 S.W.G. For armored cables substantial clamps must be used, so designed as to grip firmly the whole of the wires of the armoring without damage to the insulation.

7. Where special earth plates are not provided extreme care must be taken to see that only such earths are used as are easily capable of carrying the maximum current which can be allowed to flow by the largest fuse used in the circuit in question. From this point of view water pipes directly in connection with the street water-mains make excellent earths.

In conclusion, the sub-committee strongly recommends that the British rule providing for the need of earthing all metal other than the conductor on circuits where medium pressures are used be extended to include low-pressure circuits also, and that it also be extended to prescribe the earthing of all metal liable to be electrically charged, such as constructional steel work.—G. S. Ram and others. Paper read before the Institution of Electrical Engineers.—*Electrical Review*, London, April 9, 1920, pp. 476-79.

MOTOR BUSES OR TRACKLESS TROLLEYS.

It has been demonstrated that the gasoline bus can be a worthy competitor of street railway systems by providing a higher class of service and charging a correspondingly higher fare. The Fifth Avenue buses of New York City and the Chicago buses are examples of such successful operation. However, experience has proven that it cannot compete in operating costs with an electric street car and cannot maintain an equal service at an equal fare, that it is unsuitable for dealing satisfactorily with heavy town traffic, that it is not adequate for dealing with peak loads and that it has no advantage over the electric car as regards schedule speed. It is then doubtful whether the gasoline bus will ever displace the street car; but this bus with very little change

from standard automobile construction can be converted into a trackless trolley, driven by railway motors, supplied with power from two trolley wires. The trackless trolley, which is a vehicle practically unknown in this country, is making an exceptionally good record for earnings and service abroad. The operating costs of such a trolley as compared with those of the gasoline bus and of the most efficient street car, the safety car, are given below:

	Cents Per Bus Mile		Cents Per Car Mile
	Gasoline Bus	Trackless Trolley	Safety Car
Maintenance of overhead	.....	0.5	0.5
Maintenance of way	.....	.....	1.5
Road taxes	0.75	0.75	.....
Maintenance of equipment	8.54	3.0	2.0
Platform expenses	8.0	8.0	8.0
Traffic expenses	0.04	0.04	0.04
Power	4.54	1.8	1.8
General	3.54	3.54	3.54
Depreciation	6.59	2.00	2.00
Total	32.00	19.63	19.38

Thus it is seen that the trackless trolley can compete with the street car. It could be built with approximately the same capacity as the safety car for a weight not to exceed 12,000 pounds, or approximately 25 per cent of the weight of the present safety car. A single motor drive with necessary control can be supplied which will permit the adoption of all the safety features now standard for the safety car. It is argued that the bus has the advantage over the trackless trolley as regards unlimited flexibility. There is little question, however, but that with the introduction of the gasoline-propelled bus the city authorities would insist on a definite route and a definite time table and, thus, it would be bound to a specified routing by ordinances or legislation as a trackless trolley would be by the reason of the overhead construction. With proper overhead construction and proper collectors, the trolley bus can have a range of operation of 15 feet either side of the trolley wires, which is ample to permit passing other traffic.

These estimates would illustrate that a bus similar to the gasoline-propelled bus could enter the urban transportation field and become a worthy competitor of the street railway system, giving equal service for equal fare. This is particularly true where the officials of railway companies have not profited by the experience gained in the application of the safety car and have not applied its principles to their transportation problems. The trackless trolley having lower operating cost than the gasoline-propelled vehicle will be successful where a gasoline bus could not operate. It seems, therefore, desirable that railway operators study their transportation problems with a view to utilizing the trackless trolley as an auxiliary to their present transportation system rather than to meet it in competition.—H. L. Andrews, *General Electric Review*, April, 1920, Vol. 23, pp. 331-334.

BRONZE PLATING

BRONZE, a copper-tin alloy, can be plated or deposited from a bath containing potassium hydroxide 5 per cent, potassium cyanide 0.5 per cent, ammonium stannic chloride 0.38 per cent, and potassium copper cyanide 1.5 per cent. Satisfactory corrosion of bronze anodes is obtained, using a temperature of 40° to 50° C., and current density of 0.4 amp. per sq. dm. (3.75 amp. per sq. ft).

Bronze can also be deposited from a bath containing copper oxalate and tin oxalate dissolved in ammonium oxalate, together with some potassium sulphate, citric acid and ammonium citrate or similar salts. Bronze anodes will not corrode properly, hence copper anodes must be used. The tin content of the bath can be maintained by regularly precipitating the copper from a portion of it by using metallic tin. A careful adjustment of the relative quantities of copper and tin in the bath is necessary. Most trouble is caused by the poor corrosion of the bronze anodes.—F. C. Mathers and Stanley Lowder. Paper read before the American Electrochemical Society, April 10, 1920.

DESULPHATION OF POSITIVE PLATES.

THE Kansas State College has devised the following method of treating the positive plates of lead cells that have become sulphated:

Remove the electrolyte, wash out the cells thoroughly with distilled water, replace the electrolyte by a 3 to 4 per cent solution of caustic soda, charge until the positive plates have regained their brown color. Sufficient soda should be added so that the solution does not become acid.

The process is said to be harmless to the battery.

CONSTANT POTENTIAL SERIES LIGHTING

UNTIL recent years street lighting in the United States has been almost exclusively by the high voltage constant current series system. This was mainly for two reasons: To the democratic character of the country only such form of lighting appeared suitable as was applicable alike to the scattered suburbs and to the more densely populated center of the city. The other reason was the electrical characteristic of the arc which was the only illuminant of sufficient intensity and efficiency for street lighting. However, with the gradual disappearance of the arc lamp disappeared the necessity of the constant current circuit. The gas-filled mazda lamp is taking the place of the arc lamp. This mazda lamp represents a dead resistance, equally stable on constant potential as on constant current, and while the necessity of using high voltage still remains, especially in American cities with their large street-lighting districts, the need of the constant current system has ceased, and high-voltage constant potential series system becomes possible.

The foremost disadvantage of the constant-potential series system is its lesser flexibility; in such a system the number of lamps is given by the circuit voltage. Thus from a 2,300-volt constant-potential supply could be operated $2300/45 = 51$ 300-watt 45-volt lamps, neither more nor less. This limitation is overcome by the use of transformer taps and idle regulating reactors which can easily afford a 20 per cent range of load, and this would probably be sufficient for most purposes. A further disadvantage of the constant-potential system is its sensitivity to grounds. If two dead grounds occur in the same circuit, the current in the remaining part of the circuit is increased, and if the short-circuited part of the circuit is considerable, all the lamps in the remaining circuit may be burned out. How serious this is depends on the quality of the circuit. However, with any reasonably well built and operated circuit, the probability of two dead grounds in the same circuit should be so remote as hardly to require much consideration.

On the other hand, the great advantage of the constant-potential series system is its high power factor of 95 to 99 per cent, the better efficiency, and especially that it requires no station apparatus, such as constant-current transformers, but can and would be operated from a transformer on a pole in the distribution system, just like domestic lighting, and the mass of lines or cables running back to the stations, which are characteristic of the usual constant-current systems, due to the limited power per circuit, thus is eliminated.

In such constant potential series of lighting system all the street lighting, all the street lighting circuits may be operated from one single feeder or a few feeders which are connected or disconnected from the station at the proper time, a still more simple and convenient method is to connect the constant-potential transformers on the poles in the street lighting district, which operate the street lighting, to the domestic lighting feeders in their respective territory. This latter, however, requires some means of connecting and dis-

connecting the street-lighting transformers at the proper time of starting or stopping the street lights, since the domestic lighting feeders are continuously alive. Such may be done by manual operation, or by cascade operation; also time switches or pilot circuits may be used. Still another method which in many cases is very promising is the use of the phantom switch, that is, a switch operated with direct current by a polarized relay, so that one direction of the direct current closes it, the opposite direction opens it, with the direct current sent to the switch, such as are extensively used in telephony. Such arrangement permits electrical long-distance operation without any additional circuit.

Comparing then the three types of high-voltage street-lighting systems, the constant-current series system, the constant-potential series system and the constant potential multiple system, we have:

	CONSTANT-CURRENT SERIES SYSTEM	CONSTANT-POTENTIAL SERIES SYSTEM	CONSTANT-POTENTIAL MULTIPLE SYSTEM
(1) Type of lamp	Arc lamp or incandescent lamp	Incandescent lamps only	Incandescent lamps only
(2) Station apparatus	Constant-current transformer or reactor, etc.	No station apparatus	No station apparatus
(3) Number of station circuits	A separate circuit for every lighting circuit	No special circuit from station	No special circuit from station
(4) Number of wires per circuit	Single-wire circuit	Single-wire circuit	Two-wire circuit
(5) Accessories at lamp	Film cut out, or auto transformer or series transformer	Auto transformer or series transformer	Constant potential transformer
(6) Size of circuits	Limited number of lamps per circuit	Limited number of lamps per circuit	Unlimited number of lamps per circuit
(7) Flexibility	Great flexibility in number of lamps	Lesser flexibility	Great flexibility in number of lamps
(8) Power factor	80 to 85 per cent with incandescent lamps; 70 to 75 per cent with arc lamps	95 to 99 per cent	Practically unity
(9) Safety	High voltage at lamps except when using transformer	High voltage at lamp except when using transformer	Low voltage at lamp

—CHARLES P. STEINMETZ, *Journal of the American Institute of Electrical Engineers*, March, 1920.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

POWER TRANSMISSION BY SONIC WAVES.

By J. HERCK.

ALL methods of power transmission may be divided into three basic classes. First, the rigid transmission from solid body to solid body, as in gearing, bolt and other friction drive methods; next, transmission by fluid under pressure, no matter what the nature of the fluid may be—water, air or even electricity (direct current); third, so-called sonic waves of M. Constantinesco, a Roumanian engineer, who is said to have spent close to twenty years in the development of his idea.

The employment of sonic waves is based on experimental work which is said to have demonstrated that, contrary to popular impression, liquids are essentially compressible.

Let us consider now a conduit having a piston at each end, A and B, and entirely filled with a liquid, the pistons being leak-proof. If, now, the piston A is given a sudden impulse the liquid will be compressed, the volumetric compression storing up in the liquid a quantity of energy proportional to the coefficient of elasticity of the liquid. Furthermore, since the deformation produced is assumed to have been sudden a wave is created in the liquid and moves through it with the velocity equal to $\sqrt{\frac{E}{m}}$, where E is the coefficient of elasticity of the liquid and m is the mass per unit of volume; this velocity is the same as the velocity of propagation of the sound in a given liquid.

If the length of the conduit be properly selected, the wave will cause the piston B at the other end to move and if a vibratory motion be imparted to the piston A the piston B will receive the same motion, the conditions being somewhat analogous to what takes place with single-phase alternating current in electricity.

The intercalation of an auxiliary reservoir creates a capacity having the same effect as a condenser in an electric circuit; a spring in the circuit, by its inertia, performs the same functions as a self-induction coil, and the resistance in the conduit to the passage of the wave reminds one of an electric reactance, while the average pressure produced may be compared to the voltage in an alternating-current circuit.

The tube itself, which must be sufficiently thick not to burst under the pressure produced, introduces an accessory capacity which should be taken into consideration in the same manner as the capacity of a submarine telegraph cable is considered.

The analogy between the sonic waves and the transmission of power by alternating current can be carried still further. If we take three conduits interconnected between them and having impulses spaced 120 deg. apart, we obtain three waves spaced likewise 120 deg. apart and we have something similar to three cables carrying the three-phase alternating current—in this case only sonic instead of electric. All that is necessary to create it is three pistons placed star-wise while at the receiving end two arrangements may be employed depending on whether it is desired to have a synchronous or asychronous motor. The original article shows several diagrams illustrating the principle of these constructions.

It is interesting to note further that the transmission of energy in sonic waves is governed by laws showing remarkable analogies with such laws of electric circuits as the Ohm law, the Joule law, etc.

The Constantinesco principle has been applied for numerous purposes during the war when the inventor was working for the British Admiralty. Among these may be mentioned the hydraulic hammer with the "single-phase" sonic motor; another type of hammer for chipping stone; drills with two-phase asynchronous sonic motors, very powerful for their small size; servo motors for use on aeroplanes; and, what is

of particular interest, a device for oil injection on Diesel engines. This device has been applied by the British Admiralty to a 1,000-hp. Diesel engine and is said to have given entire satisfaction.

Another interesting application of the same principle has been made in connection with bomb throwers capable of hurling a bomb weighing 220 lb. to a distance of close to 5,000 feet, and that without either fire or noise. In this device the energy of a small cordite cartridge is absorbed in the compression of a liquid which restores it by pushing the bomb under constant pressure over the entire length of the gun barrel, which affects the efficiency of the explosion very favorably.

It is stated that experimental work is being carried on to apply the same principle to the power transmission between the engine and propeller of an aeroplane.

The best known application of the Constantinesco principle is in synchronizing the propeller and the machine gun on aeroplanes, extensively used by the Allied armies during the recent war.—J. Herck in *Bulletin Technique du Bureau Veritas*, Vol. 2, No. 4, April, 1920, pp. 69-73.

A POWER RECUPERATING ENGINE.

GEORGES FUNK, writing in *The Automobile Engineer* for April, 1920, pp. 145-153, discusses the design of engines that

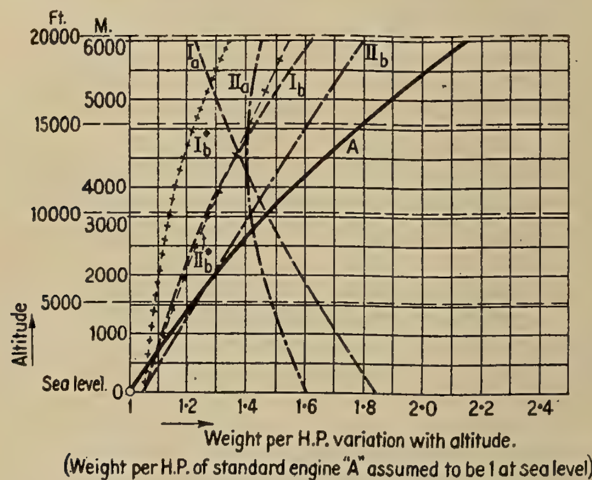


FIG. 1. CURVES OF WEIGHT PER HORSE-POWER OF ENGINES OPERATING ON VARIOUS CYCLES AS COMPARED WITH A STANDARD ENGINE AT SEA LEVEL (A)

would maintain power at altitude with supercharging. The writer discusses the operation of standard engines under various conditions on the basis of their entropy.

The power recuperating engines are classified into two main curves, the first group consisting of those having a cycle of operations such as to maintain a maximum pressure and the group to maintain a constant compression temperature taken into account for both the atmospheric temperature variation.

They may further be divided into certain subdivisions. Thus, case *a* represents an engine designed with a combustion space of such a size that its ratio to the total cylinder volume gives a maximum compression ratio required for the altitude at which the engine has been designed to work.

In order to vary the effective actual compression ratio as required by the altitude, it is proposed to close the inlet valve before the piston reaches the end of the stroke which amounts to having an engine with a variable compression but a constant expansion stroke.

This cycle is really the Atkinson cycle, with the modification that the effective compression ratio is variable with the altitude while the expansion ratio is constant, until at the predetermined altitude the standard cycle is arrived at. In this connection Fig. 1 is of interest as showing that the weight of such an engine per unit output would be quite large at sea level.

The simplest way to perform this cycle mechanically appears to be to provide a variable inlet charge cut-off by altering the timing of the inlet valve, which could be done in several ways; for example, the valves could be operated by means of rockers mounted on eccentric pins as illustrated in Fig. 2.

By rotating on its housing H the eccentric E which carried the swivel pin S, the clearance C between the rocker R and the valve V is altered and the valve lift and duration of opening is modified, thus effecting the inlet charge cut-off.

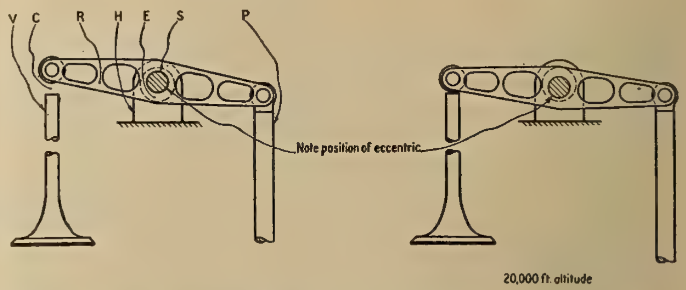


FIG. 2. VALVE OPERATION OF ATKINSON CYCLE POWER RECUPERATING ENGINE

Case *b* represents an engine so designed that the volume of combustion space is adjustable. Attempts to do this were made by introducing the piston in the upper end of the cylinder, so located that its combustion can be modified at will, thereby reducing or enlarging the combustion space. This involves a complicated and inefficient valve gear. Another proposition has been made to make the whole cylinder movable up and down, which is again too complicated for immediate consideration.

The variable stroke method has been proposed. The design of a variable stroke engine of the multi-throw type of crankshaft presents mechanical difficulties. It is, however, comparatively simple in connection with radial engines. Thus, Fig. 3 shows the design of a radial power recuperating engine.

Over the crank pin C is fitted an eccentric sleeve D, which carries the connecting rod A mounted on ball bearings in the usual manner. The eccentric sleeve can be rotated partially round the crank pin and held in any desired position. It is obvious that by this arrangement the stroke of the piston can be altered at will. Only a small eccentricity is required to give the desired result. Even in the extreme case of group 1, to which the curves relate, an eccentricity of 5 per cent of the shortest stroke is all that is necessary to effect power recuperation up to 20,000 feet.

In order to operate this eccentric sleeve from outside, a

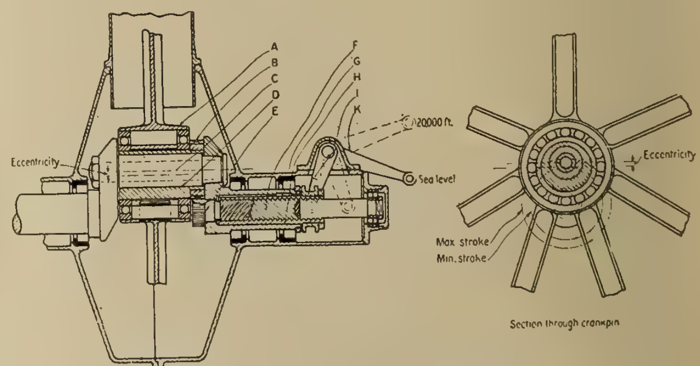


FIG. 3. RADIAL POWER RECUPERATING ENGINE

gear wheel B is attached to the sleeve. Into this gear meshes another wheel E carried on the spindle F, the latter being provided with a multi-start quick thread as shown. A sleeve H with a corresponding internal thread engages the thread of the spindle F. This sleeve is prevented from rotating by one or more keys G lodged in the crankshaft in such a manner that an axial sliding motion can be imparted to the sleeve

H by means of the lever I. It will be seen that by operating the outside lever K, which is coupled direct with lever I, the eccentric sleeve D can be rotated to any desired position, and maintained there while the crank is revolving, modifying the effective throw of the crank and thereby the piston stroke.

As the eccentricity is very small, the reaction of the connecting rods while under load on the eccentric sleeve is small, and no undue force would be required to operate the mechanism while the engine is running. Should there be any difficulty, however, the throttle may be closed for the short period of the change, which would be effected in steps according to the altitude. However, in proportioning the lead of the multi-thread and the levers correctly, this process of operation would hardly be necessary. For the same reason the different positions of the eccentric affect the timing of the engine only to a small degree, and it should be possible to design a case so that a satisfactory timing for all altitudes is arrived at, or such a timing may be evolved which gives the best result at the altitude at which the engine is called upon to run normally.—*The Automobile Engineer*, Vol. 10, No. 137, April, 1920, pp. 145-153.

SHIPYARD CRANE.

A large number of European yards adhere to the ordinary mast and derrick shipyard crane. Invariably the hoisting winch, whether steam or electric, was placed on the ground level with the attendant trouble of having the hoisting rope leading from the winch to the derrick mast always entangled in bars and plates and all sorts of rubbish. This arrangement also necessitated having signal men placed here and there, as the winch operator could not as a rule see what he was doing.

Other yards are equipped with expensive overhead traveling cranes, such as gantry cranes, or with cantilever cranes common to two contiguous berths and running either on rails laid on the ground or on a high gantry erected between the berths. Revolving cranes are also used, either of the high-power type traveling on rails laid on the ground or a small revolving crane running on rails laid on a gantry erected between berths.

The author of the paper investigated the crane arrangements on some two score of plants and found that, on the whole, nobody seemed satisfied with the crane arrangements he possessed, and the cranes not only were not standardized, but it was almost always the case that a different system of cranes were tried at almost every building berth in the same yard and for every new berth laid down.

The conclusions to which the author came as regards the general principles of crane construction are as follows:

1. The mast and derrick arrangement is quite satisfactory, provided it can be so arranged that all side staying of masts can be done away with.

2. The operator's platform should be placed high above the ground on, for instance, the level of the principal weather deck of the ship, so that the operator can see what he is doing, thus obviating the necessity of using signal men.

3. The lead from the hoisting winch to the derrick mast should not be taken along the ground among staging uprights, shoring, plates and bars, and various rubbish strewn about the ship. The lead from the winch should be free from all obstructions.

4. A space or passage-way is desirable between contiguous ships to enable building material to be brought down between ships and hoisted on board from the nearest point at the ship's side, and not from the ship's end only. Such an arrangement covers many more chances of rapid building than an arrangement based, for instance, on the material being taken in hand by the hoisting gear at the end of the ship only, because the former arrangement offers so many more points of attack on the ship than the latter.

Guided by these conclusions he designed the stationary crane shown in Fig. 3. This type is chiefly composed of a stationary main structure and two swinging arms, the former consisting of two lattice-work masts placed about 15 ft. 3 in. apart from center to center, and rigidly connected to one another by cross stays and trusses making the main structure stable in the thwartship direction, thus obviating the necessity of fitting side stays. The author calls such a structure consisting of two derrick masts rigidly connected to one another by cross stays and trusses a derrick frame in contra-distinction to the solitary derrick mast. Each derrick frame carries two derricks or arms A which can swing about 120 deg. to each side of a vertical thwartship plane through the derrick frame, *i.e.*, well past the center line of railway B laid down in the passage-way between contiguous ships. The derrick frame is held in place by fore and aft wire stays only. For this purpose two sets of stays are fitted, the lower ones C partly for giving rigidity to the cranes in a fore and aft direction and partly for preventing collapse of a whole group of interconnected cranes in case the top and stays R, or some of the top stays D, fitted from crane top to crane top of the group should give way.

At a suitable place above the ground two winch platforms E are built into the derrick frame, one above the other. Access to them is given by ladders inside the frame legs E.

Each crane arm and the load are controlled from the platforms E by a single ordinary alternating-current electric

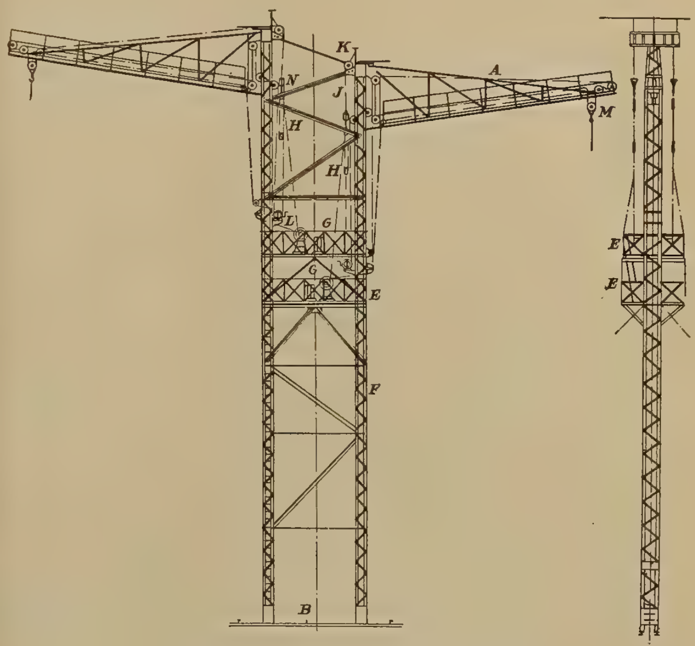


FIG. 4. HOK SHIPYARD CRANE

shipyard winch G, which means that they are controlled by one electric motor only. Hoisting and lowering are done with the winch center barrel in the ordinary way, and slewing with the extended winch ends by taking a couple of turns round the appropriate extended winch end with a loose end of a tackle H, actuating the wire J, which is carried round and fastened to the rim of the horizontal wheel K on top of the crane.

A spiral spring N is introduced above the slewing tackle for the purpose of taking up the inertia of the crane arm when it arrives at the extreme end of the swing, in this way preventing damage and unnecessary straining of the connections in case of rough usage or ignorance on the part of the man handling the crane.

The method of racking motion is described in some detail, as well as the method of erecting these cranes.—Paper read before the Institute of Engineers and Shipbuilders in Scotland, abstracted through *Marine Engineering and Canadian Merchant Service Guild Review*, Vol. 10, No. 4, April, 1920, pp. 84-87.

Progress in Mining and Metallurgy

Abstracts of Papers to be Read at the Fall Meetings of the A. I. M. M. E.

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

FLUE-TYPE COTTRELL TREATER.

By A. B. Young.

This paper describes a Cottrell treater that was placed in operation in April, 1919, at the Tooele plant of the International Smelting Co., to recover solids from the gases from the McDougall roasting furnaces. Fundamentally, the treater is simply a flue containing rows of vertical plates, forming the grounded electrode, alternated with rows of small horizontal pipes, forming the negative electrode, with proper provision underneath for taking away collected dust. There are advantages in construction over the more cumbersome types, both the vertical-tube and the vertical-box, particularly in the elimination of heavy supporting columns and massive foundations, giving a much lower first cost. There are no right-angle turns to interfere with gas distribution, consequently there is greater efficiency; that is, a greater volume of gas per minute can be effectively treated. Another advantage of the horizontal installation over the vertical is that the principle of the selective precipitation of the various components of the dust and fume as they pass along the electric field may be utilized. Since the treater has been placed in operation, the results have been quite satisfactory and, in many ways, particularly in regard to the volume of gas that may be treated, have greatly exceeded expectations.

The outstanding features are the constantly decreasing copper values and increasing lead values as we proceed along the treater toward its discharge end, with the result that a portion of dust collected may be segregated and smelted for its lead content. An examination of the figures for iron and insoluble matter bears out the idea that there is a marked tendency to precipitate the true dust particles near the entrance, and that the more impalpable fumes must travel a greater length through the electric field before being caught.

It is extremely difficult to state, with any degree of accuracy, the power input into the treater, other than that it is much lower than one would expect and is quite variable. For normal gas volumes (125,000 to 150,000 cu. ft. per min.), the input of power will average very closely to 8.4 kva. for the first electrical section and 5.5 kva. for the second. Approximately 85 per cent of the dust caught is collected by the first, and 15 per cent by the second section.

This form of installation has proved admirably adapted to these particular gases. No data are available as to its ability to treat satisfactorily a purely fume product. However, when one compares this compact flue-like building, which is efficiently handling 150,000 cu. ft. of gas per min., with the complex towering structures of the vertical type necessary to treat this amount, one is convinced that a distinct step forward has been taken.

UTILIZATION OF TITANIFEROUS IRON ORE.

By J. A. Heskett.

New Zealand is dependent on the outside world for its ferro products yet it has at least two well-defined iron-ore deposits, the Para Para limonite, and the Taranaki iron-sand, a combined magnetite and ilmenite. This latter deposit forms the greater portion of the beach sands of the west coast of the North Island of New Zealand. To all appearances it is a chemical compound of the double oxides of iron and titanium and not a mechanical mixture.

Knowing the difficulty with which the iron-sand is reduced, the writer conceived the idea that if the reduction were made largely a direct one the chances of reduction would be more complete and the gases would be richer in carbon monoxide, which in turn would give a desired result. By mixing coking coal and fine iron-sand in the proportion of 1 to 1, coke or ferrocoke, that ran 36 per cent metallic iron and 40 per cent carbon was obtained. At the same time a greater portion of the oxide was reduced to a metallic state in the 8 hr. that elapsed in the coking process. This ferrocoke was charged with the limestone into the experimental furnace, which was like a foundry cupola. It was 8 ft. from charging door to tuyeres, 3 ft. in diameter, and was served with four tuyeres with a 6-oz. blast pressure. It was water-jacketed and had water-cooled tuyeres.

After repeated experiments, this process was abandoned because the friable nature of the ferrocoke at an incandescent temperature caused a congestion of finely divided coke, which became entrapped in slag and gradually contracted the working area of the hearth.

Because of the indifferent quality of iron produced by the cold-blast practice a hot stove was installed and the existing furnace heightened. Eventually the U-pipe hot blast was installed and the process was brought more in keeping with modern practice of ore reduction, relying on a greater percentage of indirect reduction. The amount of pig iron produced was 50 tons, averaging 5 tons per day.

The slags were fluid and no trouble was experienced in their handling. In fact, the titanic-acid content would lead one to believe that it had lowered the fusion point as well as the viscosity of the slag. At times the titanic-acid content was brought up to 20 per cent as an experiment, on subsequent trials, and the fluidity was in no way impaired, so the theory of viscid slags due to normally high titanic-acid content might easily be dispelled.

Whether the practice of mixing equal parts of nontitaniferous and titaniferous ores, as practiced at Port Henry, N. Y., is beneficial to foundry practice remains to be seen. Our experience is that the pig iron producd from titaniferous ore will not grain out as will other iron of similar analysis. It has a ready tendency to chill even in ordinary sand casting with 2.5 per cent silicon and 0.04 per cent sulfur. This chill is only to a depth of 1/32 in. The iron is exceptionally strong and tough, easily standing 25 per cent greater breaking strain and deflection. Castings made from this iron have a wonderful finish, surpassed by no other iron used in the writer's foundry experience. Where extreme softness is required in thin castings some founders object to this iron. It is more adapted to steel production than every-day foundry iron, and the steel produced has exceptional strength, ductility, and malleability.

NEW METHOD OF MAKING FIFTEEN PER CENT PHOSPHOR-COPPER.

By P. E. Demmler.

Phosphorus combines with copper in various proportions, forming true alloys, some of commercial importance, which find wide application as deoxidizers and as a means of introducing phosphorus into other alloys, as in phosphor-bronze. Phosphor-coppers containing 10 and 15 per cent phosphorus are the commercial grades most generally offered.

Processes for making phosphor-copper may be divided into two classes: (1) Those depending on the smelting of phosphate rock or superphosphate of calcium with copper or copper-

bearing materials, and coal or other carbonaceous material; (2) those depending on the direct combination of metallic copper and elemental phosphorus.

Among the objections to the first method of producing phosphor-copper are the large amounts of raw material and resulting slag to be handled, and the difficulty of getting a satisfactory fusion.

Methods of the second class are generally used. The usual practice is to add the phosphorus to the molten copper by means of phosphorizers. This method entails a phosphorus loss of at least 25 per cent, and there is danger of burns to the workmen. Various methods have been suggested for obviating these objections.

Experiments of the author have shown that a uniform 15 per cent phosphor-copper could be produced by passing phosphorus vapor over heated copper. The most satisfactory temperature of the copper was found to be 400°C. Phosphorus boils at approximately 290°C and when this vapor passes over heated copper, combination takes place immediately with incandescence and incipient fusion. Pieces of copper wire up to ¼ in. in diameter are completely phosphorized by this method.

An apparatus having a capacity of about 130 lb. of phosphor-copper was constructed to demonstrate the commercial value of this method. This apparatus consists of a retort for heating and distilling the phosphorus, a container for the copper, and fittings to connect the two. Suitable supports are also provided. The apparatus is made entirely of iron, which is not attacked by phosphorus at the temperature of the operation. Means are provided for heating the phosphorus and copper separately.

To operate, phosphorus is placed in the retort, clean copper scrap (such as wire, turnings or millings) is placed in the copper container, and the two are connected. Tight joints should be made by using suitable gaskets to prevent loss of phosphorus. A hole drilled into the plate covering the end of the copper container prevents increase of pressure within the apparatus. The copper is heated to 400°C. before heat is applied to the phosphorus. With the small apparatus phosphorus has been distilled at the rate of 30 lb. per hour.

Phosphorization to 15 per cent phosphor-copper takes place in one step, no intermediate products being formed if conditions as to temperature are observed.

The method of making 15 per cent phosphor-copper, outlined above, had the following marked advantages: The copper need not be heated over 400°C,; the phosphorus need not be handled near hot or molten metal; there is no loss of phosphorus; and the product is uniformly 15 per cent phosphor-copper.

CARE OF ROCK DRILLS.

By HOWARD R. DRULLARD.

TO OBTAIN the best results from hammer drills, close attention must be paid to lubrication and the shank. With the exception of stoping drills, most modern rock drills require both oil and grease. Ordinary machine oil is not adapted to rock drills; a heavier more gelatinous oil, such as castor machine oil or liquid grease, should be used. Hard grease must not be put into the lubricators, as it will not flow through that part. Contrary to the popular belief, oiling a machine once or twice a shift is not sufficient; the drills should be oiled once for every 12 or 14 ft. of hole drilled. Stoping drills require oil at least twice a shift; lighter oils than castor, such as Arctic Ammonia, may be used.

Drills used in shaft sinking can be oiled satisfactorily by placing a good-sized, drop, sight lubricator on the station above the sinking operations and connecting it with the air-line supplying the sinking drills. If the lubricator is properly filled and adjusted, a uniform oiling will be effected without oiling the drills individually. The grease end should be filled at the station or surface before each drilling period. The shift boss should see to it that the machines are greased and also that the lubricators at the station function properly. The life of the air-drill hose is somewhat shortened by this method, as oil attacks the inner tube, but as some oil is always present in the compressed air, this is not a serious objection.

DRILL SHANKS.

The method of forming drill shanks on a standard drill sharpener is simple and quite generally understood. The shanks, however, must be accurately made and maintained to the dimensions; a variance of ¼ in. in length will often reduce the drilling speed of the machine 25 per cent.

Close attention must also be paid to the shape and location of the hole made to accommodate the water tube. To avoid excessive breakage of water tubes, this hole must be 5/16 in. in diameter and punched to a depth of at least 3 in. It must be in the center of the steel, and after punching should be counterpunched slightly to prevent formation of a sharp edge that will cut off the water tube. The shank, of course, should present a smooth striking face.

The shank when properly formed is hardened. The operation is simple, involves no delicate judgment of temperatures or high mechanical skill, can be learned by any intelligent blacksmith in a few moments, and gives a shank so hardened that it will not batter, break, or damage the piston hammers of the rock drills.

The proper treatment of the shank begins in the forging. The steel must not be overheated; that is, it must not approach a white heat. The steel must not be allowed to "soak" in the fire, as this causes scaling; an unduly high air pressure in blowing the forge will also cause the steel to scale, and a scaled shank will not respond properly to the hardening process. After forming, the shanks should be annealed by being cooled gradually; preferably, they should be covered with lime or ashes and allowed to cool.

Either fish or linseed oil is satisfactory for hardening, although other light oils are at times used. The quantity required is proportionate to the number of shanks to be hardened at one time. Five gallons will suffice for the hardening of three or four shanks, but if considerable steel is being worked, 45 or 50 gal. are advisable. A rectangular tank in which the steel can be stood up conveniently is generally used. The oil must be kept free from any foreign matter, particularly water.

The shank should be heated to a cherry red at the striking end with the heat graduated to a dull red just beyond the collars, or lugs; or, in the case of the shankless stoping steel, to a point about 4 in. from the end. The shank is then plunged into the oil and allowed to cool thoroughly.

Each and every shank must be so hardened that it can be readily cut with a file. The shanks must be softer than the piston hammers or damage to both will result.

Correspondence

The editor is not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.

MERCURY ARC RECTIFIERS

To the Editor of the Scientific American Monthly:

The abstract "Mercury Arc Rectifiers for Large Outputs," appearing in Scientific American Monthly, 1920, Vol. 1, No. 3, page 279, contains the following statement:

"The favorable results obtainable with apparatus of low output encouraged the Société Anonyme, Brown, Boveri & Co. to investigate the question of building rectifiers for large outputs.

"A rectifier company was formed by the firm in 1912 in Glaris (Switzerland) for the purpose of carrying out the necessary experimental work and the technical staff of this company soon made the acquaintance of numerous difficulties of a practical nature."

The writer may be permitted to point out that this statement is not correct.

The Brown-Boveri rectifier was not developed by mentioned firm nor by the rectifier company in Glaris (Switzerland), but by the firm Hartmann & Braun, located at Frankfurt (Germany), where the large capacity rectifier system Schaefer was developed (compare *Electrotechnische Zeitschrift*, page 2, 1911). In 1913 Brown-Boveri took over the patents of Hartmann & Braun respectively. Schaefer and the technical staff responsible for this design entered the firm of Brown-Boveri in Baden (Switzerland), partly as directors.

At this occasion it may be stated that it was the writer who took up first rectifier work in Switzerland by making an extensive experimental and theoretical investigation[1] on the mercury arc rectifier (Cooper Hewitt rectifier). Incidentally, the writer invented a basic principle[2] especially fitted for mercury arc rectifiers of tremendous capacity. (Compare *Schweizerische Bauzeitung* No. 13, 1920, page 147.) As the original Cooper Hewitt patent still controlled the Brown-Boveri respectively Hartmann-Braun Schaefer patents the mentioned firm was dependent upon the Cooper Hewitt, respectively Westinghouse firm.

The article, "Mercury Arc Rectifiers for Large Outputs" contains also the following statement:

"The losses in the mercury arc rectifier are equal to the product of the current and the pressure drop across the arc, etc. The losses, therefore, for a given working pressure are equal to the load current multiplied by a constant, this constant being the voltage drop across the arc so that the efficiency of the rectifier is the same for all values at all loads."

The writer having made extensive investigations on this subject[3] can only state that this statement is clearly erroneous. In the mentioned articles the writer has clearly shown how all the losses in a rectifier can be determined and it would be highly desirable that such unreliable statements as mentioned above would disappear from the technical literature.

Wm. Tschudy.

Yonkers, N. Y.

[1] Experimentelle Untersuchungen am Aueck silber dampfgleichrichter für Wechselstrom. Thesis Federal Technical University Zürich, 1912.
Bulletin des schweizerischen Elektrotechnischen Vereins, 1912.
Über die Entwicklungsmöglichkeiten des Quecksilberdampfgleichrichters auf grund experimenteller Untersuchungen.
Zeitschrift für elektrische Kraftbetriebe und Bahnen, 1913.

[2] German patent No. 255547, American patent No. 1189887 reissue No. 14816.

[3] See former mentioned articles.
Electrical World, 1916.
Elektrotechnische Zeitschrift, 1917.
Electrical World, 1918.
Schweizerische Bauzeitung, 1920, p. 147.

"STANDARDS FOR SCREW THREADS."

To the Editor of the Scientific American Monthly:

The article in February issue entitled "Standards for Screw Threads" has been read with considerable interest, and the writer commends its clearness and hopes it will be widely read. Its appearance at this time is a very good education for the general public, because the proposed standard of the National Screw Thread Commission, appointed by act of Congress, will be issued very shortly, and the terminology in above mentioned article agrees with that of the National Screw Thread Commission's report.

The cuts and description of threads and the fit of mating parts are clearly shown in your article and a little analysis of these would show why any trouble exists in making proper fits from a theoretical standpoint.

Theoretically, there is nothing mysterious about a thread fit—it is simply the number of factors involved. A good cylindrical fit depends on the size, rotundity and parallelism of the mating surfaces. A good sliding fit (rectangular or otherwise) depends on the size, parallelism, and contour of the mating surfaces. A good thread fit depends upon size, rotundity, parallelism, lead and contour of the mating surfaces. Fulfilling these requirements practically becomes more difficult in proportion to the number of factors involved. The important factor in all tight fits and the one thing that the average mechanic entirely loses sight of is the "flow of the metal," due to the plastic nature of the metal.

The writer believes it is a fundamental fact that force fits cannot be made between mating parts unless there is either elasticity or flow of the metal.

Take a ring and plug gage which are correct and the plug can be passed freely through the ring by a skillful man. Cover the mating surfaces with oil, and it requires force to get the plug through, the same will be true if the plug were, say, ½ thousandth of an inch larger. Careful measurements will disclose that the ring has expanded or stretched, and the tightness of fit is due to the tension of the metal in the ring or its elasticity. If the ring were made so large it could neither expand nor the metal compress, and a hardened plug were driven in, the plug would be longer after being driven in because it "drew" out in length, thus being easier than moving the metal of the large ring. It will be found nearly impossible to force a fit unless the metal of one or both moves.

This flow of metal is a phenomenon taken advantage of by many artisans, but seems to be lost sight of in thread fits. The accurate production of all the factors involved in a good thread fit is practically impossible, and even in the best of gage work small tolerances are permitted to avoid prohibitive cost so that even these precision gages do not exactly fit. When this condition is realized, it must be evident that commercial screw thread product is far from this accuracy, yet must go together to function properly. It does this in all fits except the loose ones, because the metal flows and the crest and root clearance is a space provided for the excess metal, due to both contour and lead, to flow into.

All tight nuts, if forced on several time with oil on the mating surfaces, will approach an apparent good fit, that is, the metal will flow so that the mating surfaces conform to each other, and it answers the purpose if not too badly off.

This feature permits interchangeability of close fits, and if it were not so, there would be but a limited interchangeability in this class of work.

The article in the February issue mentions the various systems of threads in use, and these are not all, as the records of the United States Army, Ordnance Dept., will substantiate. The writer, while in charge of the Gage Section of the Ordnance Department during the recent world war, had to contend with fifteen distinct thread systems and gage up Ordnance material made to all of them. He was Chairman of the National Screw Thread Commission on its trip abroad, studied the question of an international standard at close range, and offers the following observations:

(1) Is an International Standard for screw threads desirable?

(2) What is the best system in use?

(3) Which would give the least trouble to universally adopt?

It would seem that the answers to these would pretty nearly solve the problem so far as America was concerned, and an affirmative answer to number one will hardly be contested.

Regarding number two, those who have had extensive experience in threads of all kinds will unhesitatingly say the "American," meaning thereby the United States Standard for coarse pitches, the S. A. E. standard for fine pitches, and the A. S. M. E. for screws smaller than the first two provide for, is the best.

All things considered, the 60 degree thread is the best and easiest to produce and verify.

The truncation of the triangle to 1/8 of the pitch is satisfactory for both making and functioning. In fact, it is so satisfactory for all purposes that it is as well known and as much used in Canada as in the United States. This in itself speaks wonders for it, as Canada naturally inherited to some extent the Whitworth system from her Mother Country and supplanted it with that of a neighbor. When Canada got to making munitions for Great Britain with Whitworth threads, there was considerable trouble and they could not understand why anyone could stick to such a system when there was one so easy to make in comparison.

The French, when trying to standardize, adopted the 60 degree thread flatted top and bottom to 1/8 of the pitch, thereby concurring in its merit.

The answer to number three is best stated by saying that conferences in England developed the fact that 70 per cent of the screw thread product of the world was made to inch measurements. 55 per cent of the world's screw thread product was made to the American standard, while 15 per cent was Whitworth. All other systems, including the metric threads, made up the balance, or 30 per cent.

Therefore, one-half of the screw thread product of the world does not need changing if the American standard is adopted. Saying it another way, if any other system became the standard, this 50 per cent and either the 15 per cent or the 30 per cent additional would have to be changed to suit a very small minority.

What is more important, there is easily three times as much screw thread product in stock made to American standards as all the rest put together, and it would be nothing short of a crime to try to force any other system into use which would sacrifice this stock. It is believed that the Standards proposed by the National Screw Thread Commission will enable practically all the American threads to be used and for all loose and medium fits, those of the Whitworth system as well, excepting one size and pitch.

If England set the tolerance on the angle towards 60 degrees and America set it towards 55 degrees, the majority of work will go together and function properly, as the rounded crest and root play no part in the fit and a space is provided for it.

The only other system in enough use to mention as a possibility, is the French Internationale, and all it has to recommend it is the 60 degree thread with 1/8 of the pitch flattened. The diameters and pitches do not conform to anything else in the world and could never interchange with the American threads.

The fundamental basis of the system of pitches is built upon an ideal which is impracticable, viz.: the pitch is in millimeters from the center of one thread to the center of the next, and six to ten times this pitch is the diameter of the screw. This offers no advantage and many mechanics think it has a good many drawbacks.

The National Screw Thread Commission suggested to the French Commission that there might be a reconcilliation of pitches if a new unit of length is named which would have the value of 5 inches and 127 m/m. Then by multiplying the present American and English pitches by five and calling it the pitch in turns per the new unit of length, it offered a means of interchangeability if the French would make their pitches the same number of turns per 127 m/m, which, of course, means they would be identical. The French diameters would then become fractional millimeter sizes to interchange with American and English standards. It was pointed out that this would be the least hardship because of the great amount of screw thread product in stock in America and England.

E. C. PECK,
Vice-Chairman, Nat'l. Screw Thread Comm'n.
(Formerly Lieut.-Col. Ord. Dept.)
Cleveland, Ohio.

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Note.—Illustrated articles are marked with an asterisk (*), shorter articles and notes with the letter (n). Look for the general subject rather than the supposed specific title of any article. Thus: "Aeronautics," "Automobiles," "Meteorology," etc., will give related articles much more quickly than by reference to the title of the article.

Announcement

Owing to increased costs of paper, printing and overhead expenses we are obliged to announce a slight increase in the price of the SCIENTIFIC AMERICAN MONTHLY. On and after July 1st, 1920, the subscription price will be $5.00 per year and the price per copy will be 50 cents. Combination price of SCIENTIFIC AMERICAN MONTHLY with SCIENTIFIC AMERICAN to the same address will be $9.00 per year.

With this, the last number of the first volume of the SCIENTIFIC AMERICAN MONTHLY, we wish to thank our readers for their interest in and enthusiastic support of the new publication. We have been much encouraged by the laudatory comments received. The SCIENTIFIC AMERICAN MONTHLY aims to be of distinct service in promoting interest in the progress of science and in developing American industries to a higher plane by publishing the latest advances in various branches of technology.